620.6
ENS
v.1

THE UNIVERSITY
OF ILLINOIS
LIBRARY
620.6
ENS

REMOTE STORAGE

ALTGELD HALL STACKS

MINUTES OF PROCEEDINGS

OF

The Engineering Association

OF

NEW SOUTH WALES.

ALSO,

ACT OF INCORPORATION, RULES AND BY-LAWS,

AND

LIST OF MEMBERS.

VOL. I.

Edited by GUSTAVE FISCHER,

HON. SECRETARY ENG. ASSOC. OF N.S.W.

SYDNEY:
Published by the Association,
BANK CHAMBERS, 34 JAMIESON STREET.
1886.

(The right of Publication and Translation is reserved.)

ADVERTISEMENT.

The Association, as a body, is not responsible for the facts and opinions advanced in the following pages.

Sydney: Printed by Jas. Miller & Co., 78 Clarence Street.

620.6
ENS
v.1

REMOTE STORAGE

PREFACE.

A few remarks introductory to this Volume of Proceedings of the Engineering Association of New South Wales are on this occasion deemed advisable, for the reason that this is the first time that the Association has attempted the task of issuing a volume containing a record of its principal papers and transactions during an entire year, and therefore its publication will, in all probability, subject it to the ordeal of criticism and comparison with similar productions circulated by kindred societies. It is therefore felt that, without in any way attempting an apology for its existence, a brief explanation of the circumstances under which this volume has been prepared, and the difficulties which had to be overcome before such existence was possible, may here be fitly given, notwithstanding the fact that prefatory notices are not usually attached to the publications of professional or scientific societies.

In the first place it is necessary to point out the fact that those members of the Engineering profession who reside in a new country such as New South Wales, partly owing to their isolation from the great European centres of learning and modern scientific thought, and also in very many cases in consequence of the unsettled

Sets 2.2 Mar. 29 Stechert = v.1-11 (1886-96)

2568

687257

and variable nature of their duties precluding the opportunity for frequent contact with their fellow-workers, are not placed in an equally good position to record in suitable language the results of their labour and experience, as are those Engineers who are fortunate enough to be so circumstanced that information and assistance is available from both men and books, and the nature of whose work is such as to tend to the development of the higher or more abstract professional studies. Hence the authors of the various papers contained in this volume have had special difficulties to contend with, for which due allowance should be made.

It is also an almost invariable experience with young institutions that, during their earlier years, formidable impediments to their progress present themselves, and have to be battled with and overcome. One of the most serious of these impediments usually presents itself in the shape of want of funds, and although the finances of the Association are at present in a satisfactory condition, its income is not sufficient to enable it to reach that standard of excellence in the printing of its transactions which is characteristic of older societies. Thus the plates appended to this volume have been lithographed from tracings furnished by each contributor, thereby relieving the Association of what would otherwise have been a necessary and heavy expenditure, but this saving has resulted in a

manifest want of that uniformity of execution, style and finish, which it is so desirable to obtain, and which, it is to be hoped, will be apparent in future volumes of the Association's Proceedings.

For a similar reason some of the discussions on papers do not appear. This has been caused through the omission of speakers to supply a brief written abstract of their remarks to the editor of the volume, failing which, no record is obtained in consequence of the Association not being able to employ the services of short-hand writers.

Digitized by the Internet Archive
in 2014

https://archive.org/details/memoirs1188engi

CONTENTS.

Page.

Act of Incorporation ... ... xi.
Rules and By-laws xvii
Appendix containing forms referred to in the By-laws ... xxiv.
List of Officers and Members of Council ... ... xxvii.
List of Members ... ... xxviii.

MINUTES OF PROCEEDINGS.

8th October, 1885.

Election of Members 1
Annual Report 1
List of Original Communications—Session 1884-85 2
Premiums Awarded—Session 1884-85 4
Balance Sheet 5
Accounts of Receipts and Expenditure... 6
Election of Officers—Session 1885-86 8

12th November, 1885.

Election of Members 9
President's Address 9

10th December, 1885.

Election of Members 21
"The Treatment of Copper Ores by the Manhes Process," by Clement Van de Velde (1 Plate) 21
"The Manufacture of Bread by the Dathis Process," by Clement Van de Velde (4 Plates) 27

14th January, 1886.

Election of Members 37
'The Van Ryssellberghe System of Simultaneous Telegraphy and Telephony," by Albert Leahy (1 Plate) 37

11th February, 1886.

Election of Members 49
"Healthy Dwellings," by J. M. Smail... 49

11th March, 1886.

Election of Members 49
"Compressed Air and its Applications," by Norman Selfe (3 plates) ... 49
Discussion on ditto 77

8th April, 1886.

Election of Members 89
"On the Construction of Breakwaters and Training Jetties," by Walter Shellshear (4 Plates) 89
Discussion on ditto 120

15th April, 1886.

Page.
"On the use of Concentrated Solutions of Soda for Generating Steam," by C. Wagemann (2 woodcuts) 135

13th May, 1886.

Election of Members 149
"The Mechanics of Agriculture," by Angus Mackay 149
"Our Colonial-built Harbour Steamers," by H. Selfe 156

10th June, 1886.

"The Metallic Arch," by Francis Bergin (3 Plates) 166

8th July, 1886.

"The Manufacture of Ice by the Beth Process," by F. T. Bagshawe (3 Plates) 188

12th August, 1886.

Election of Member and Student 199
Alteration of Section V. Clause I. of Rules and By-laws 199
"Economy in Steam Navigation," by Wm. S. Bailey 199

16th September, 1886.

Election of Members, Associate and Student 220
Appointment of Auditors... 220
Alteration of Section V. Clause 1. of Rules and By-laws 220
Communication *re* forming an "Australasian Association for the advancement of Science 220
"Notes on Portland Cement," by A. C. Mountain 220
Discussion on ditto 237
Addendum to ditto 256
Index... 258

ERRATA.

Page 13, line 31 from top, read metallic instead of metalic.

Page 155, line 3 from top read logs instead of bags.

Page 175, lines 16 and 15 from bottom, should read as follows:—We may say that the stress per square inch of sectional area of any bar of iron divided by the elongation of one inch in length of the bar produced by that stress gives a

Page 176, for $\frac{l'}{l} \div \frac{s}{a} = \frac{a \times l'}{s \times l}$ read $\frac{s}{a} \div \frac{l'}{l} = \frac{s \times l}{a \times l'}$

Page 179, line 3 from bottom, for $q \frac{h \times l}{a \times E}$ read $q^2 \frac{h \times l}{a \times E}$

Plates 14 15 and 16 should be numbered 16 14 and 15 respectively.

Plate 14, Fig. 7, join the points c and d.

Plate 15, line 10 from bottom, for "squre" read "square."

ACT OF INCORPORATION.

THE ENGINEERING ASSOCIATION OF NEW SOUTH WALES INCORPORATION.

An Act to Incorporate a Society called the "Engineering Association of New South Wales." [19th August, 1884.]

WHEREAS a Society called the "ENGINEERING ASSOCIATION OF NEW SOUTH WALES" has under certain rules and by-laws been formed at Sydney in the Colony of New South Wales for the general advancement of Engineering and Mechanical Science And whereas the Council of the said Society is at the present time composed of the following office-bearers and members Owen Blacket Consulting Engineer President Henry Selfe Government Engineer Surveyor Vice-President John Sands Mechanical Engineer Honorary Treasurer John Parry Honorary Librarian William Eugene Hort Nicolle Secretary and John Trevor Jones City Engineer Adrien Charles Mountain City Surveyor Walter Shellshear Assoc. M. Inst. C.E. Henry Davies Civil Engineer Max Thomson Civil Engineer and Robert Pollock Mechanical Engineer Members of the Council And whereas it is expedient that the said Society should be incorporated and should be invested with the powers and authorities hereinafter contained Be it therefore enacted by the Queen's Most Excellent Majesty by and with the advice and consent of the Legislative Council and Legislative Assembly of New South Wales in Parliament assembled and by the authority of the same as follows:— Preamble.

Interpretation Clause.

1. For the purposes of this Act the following words in inverted commas shall unless the context otherwise indicate bear the meaning set against them respectively—

"Corporation"—The Society hereby incorporated.

"Council"—The members of the Council at any duly convened meeting thereof at which a quorum according to the by-laws at the time being shall be present.

"Secretary"—Such person or either one of such persons who shall for the time being be the Secretary or Secretaries honorary or otherwise of the said Society (saving and excepting any Assistant Secretary of the said Society).

Incorporation Clause

2. The President Vice-President Officers and Members of the said Society for the time being and all persons who shall in manner provided by the rules and by-laws for the time being of the said Society become members thereof shall be for the purposes hereinafter mentioned a body corporate by the name or style of the "Engineering Association of New South Wales" and by that name shall and may have perpetual succession and a common seal and shall and may enter into contracts sue and be sued plead and be impleaded answer and be answered to defend and be defended in all Courts and places whatsoever and may prefer lay and prosecute any indictment information and prosecution against any person whomsoever and any summons or other writ and any notice or other proceeding which it may be requisite to serve upon the Corporation may be served upon the Secretary or one of the Secretaries as the case may be or if there be no Secretary or if the Secretaries or Secretary be absent from the Colony then upon the President or Vice-President.

Rules and By-laws.

3. The present rules and by-laws of the said Society shall be deemed and considered to be and shall be the rules and by-laws of the said Corporation save and except in so far as any of them are or shall or may be altered varied or repealed under the powers for that purpose therein contained or are or may be inconsistent or incompatible with or repugnant to any of the provisions of this Act or any of the laws now or hereafter to be in force in the said Colony.

Power to hold and deal with lands.

4. The Corporation shall have power to purchase acquire and hold lands and any interest therein and also to sell and dispose of the said lands or any interest therein and all lands tenements hereditaments and other property of whatever nature now belonging to the said Society under the said rules and by-laws or vested in Trustees for them shall on the passing of this Act be vested in and become the property of the said Corporation subject to all charges and claims and demands in anywise affecting the same.

Property vested in Corporation

Ordinary business to be managed by the Council.

5. The ordinary business of the Corporation in reference to its property shall be managed by the Council and it shall not be lawful for individual members to interfere in any way in the management of the affairs of the Corporation except as by the rules and by-laws for the time being shall be specially provided.

Powers of Council.

6. The Council shall have the general management and superintendence of the affairs of the Corporation and excepting the appointment of Presidents and Vice-Presidents and other honorary officers who shall be appointed as the by-laws of the Society shall from time to time provide the Council shall have the appointment of all officers and servants required for carrying out the purposes of the Society and of preserving its property and it may also define the duties and fix the salaries of all officers Provided that if a vacancy should occur in the Council during any current year of the Society's proceedings it shall be lawful for the Council to elect a member of the Society to fill such vacancy for the unexpired portion of the then current year. The Council may also purchase or rent land houses or offices and erect buildings or other structures for any of the purposes for which the Society is hereby incorporated and may borrow money for the purposes of the Corporation on mortgages of the real and chattel property of the Corporation or any part thereof or may borrow money without security provided that the amount so borrowed without security shall never exceed in the aggregate the amount of the income of the Corporation for the last preceding year and the Council may also settle and agree to the covenants powers and authorities to be contained in the securities aforesaid.

Liability of Members.

7. In the event of the funds and property of the Corporation being insufficient to meet its engagements each member thereof shall in addition to his subscription for the then current year be liable to contribute a sum equal thereto towards the payment of such engagements but shall not be otherwise individually liable for the same and no member who shall have commuted his annual subscription shall be so liable for any amount beyond that of one year's subscription.

Custody and use of Common Seal.

8. The Council shall have the custody of the common seal of the Corporation and have power to use the same in the affairs and business of the Corporation and for the execution of any of the securities aforesaid and may under such seal authorize any person without such seal to execute any deed or deeds and do such other matter as may be required to be done on behalf of the Corporation but it

shall not be necessary to use the said seal in respect to the ordinary business of the Corporation nor for the appointment of their Secretaries Solicitor or other officers.

Copy of By-law to be evidence.s

9. The production of a printed or written copy of the rules and by-laws of the Corporation certified in writing by the Secretary or one of the Secretaries as the case may be to be a true copy and having the common seal of the Corporation affixed thereto shall be conclusive evidence in all Courts of such rules and by-laws and of the same having been made under the authority of this Act.

Elections not made in due time may be made subsequently.

10. In case any of the elections directed by the rules and by-laws for the time being of the Corporation to be made shall not be made at the times required it shall nevertheless be competent to the Council or to the members as the case may be to make such elections respectively at any ordinary meeting of the Council or at any annual or special general meeting held subsequently.

President, Vice-President or Secretary may represent Corporation for certain purposes.

11. The President or Vice-President or the Secretary or either one of the Secretaries may represent the Corporation in all legal and equitable proceedings and may for and on behalf of the Corporation make such affidavits and do such acts and sign such documents as are or may be required to be done by the plaintiff or complainant or defendant respectively in any proceeding to which the Corporation may be parties.

12. This Act may be cited as the "Engineering Association Incorporation Act of 1884."

RULES AND BY-LAWS.

RULES AND BY-LAWS.

Section I.

OBJECTS.

The Engineering Association of New South Wales was first established, and has since been incorporated by Act of Parliament, for the general advancement of Engineering and Mechanical Science, and more particularly those branches of Civil and Mechanical Engineering which tend to develope the resources of Australia, and to receive and discuss at its stated meetings original papers on Civil and Mechanical Engineering.

Section II.

CONSTITUTION.

1. The Engineering Association of New South Wales shall consist of Members who are entitled to the privileges of Corporate Membership, also Honorary Members, Associates and Students, who are not entitled to the privileges of Corporate Membership.

2. Every Candidate for election into the class of Member shall be more than twenty-one years of age, and must be actually engaged in some branch of Engineering, and must be considered by the Council to be qualified for election.

3. Associates to be gentlemen not under twenty-four years of age, who from their scientific attainments or position in society, may be considered eligible for election by the Council.

4. Honorary Members shall be persons who have been eminent benefactors to this or some other of the Australian Colonies, and distinguished patrons and promoters of Engineering and Manufacturing industries. Honorary members shall be exempted from payment of fees and contributions; they may attend the meetings of the Association, and they shall be furnished with copies of the publica-

tions of the Association, but they shall have no right to hold office, to vote, or otherwise interfere in the business of the Association. The number of Honorary Members shall not at any one time exceed twenty, and not more than two Honorary Members shall be elected in any one year.

5. Students shall be persons not under sixteen years of age who are students in engineering at a University, or who are apprenticed or articled to any branch of Engineering, and may afterwards be admitted as Members at the discretion of the Council. Such persons may continue Students until they attain the age of twenty-two years, but not longer.

6. The Officers of the Association shall be a President, Vice-President, Secretary, Honorary Secretary, Honorary Treasurer, and six other Members of Council, being eleven persons, who shall constitute the Council to direct and manage the concerns of the Association; also two Auditors of Accounts, and a Librarian. Such officers shall be elected or appointed annually in manner hereinafter directed.

Section III.

ELECTION AND EXPULSION OF MEMBERS, ASSOCIATES, HONORARY MEMBERS, AND STUDENTS.

1. Any person desirous of being elected a Member, Associate, or Student must be proposed and recommended according to Form No. 1. All recommendations for admission to be signed by not less than five members if the application be for admission as a Member or Associate, and by three Members if it be for a Student.

2. The proposal so made being delivered to the Secretary, shall be submitted to the Council, who, on approving the qualifications of the candidate, shall present the application for ballot.

3. The elections to take place by ballot. All recommendations for admission to go to the ballot unless unanimously rejected by the Council. The approved ballot list to be signed by the President, and copies forwarded to the Members. Elections to take place at the ordinary General Meetings.

4. The proportion of votes for deciding the election of any candidate shall be at least four-fifths of the number voting, twenty members at least to record their votes.

5. Any person duly elected a Member, Associate, or Student, shall be informed thereof without delay, by a letter, according to Form No. 2, enclosing a promise (Form No. 3) to abide by the Act of Incorporation, Rules and By-laws of the Association, which promise the person elected must sign and return to the Secretary, and he must pay the admission fee and subscription for the current half-year within two months after the date of his election, which otherwise shall become void, but the Council may, in particular cases, extend the time.

6. Every person proposed as an Honorary Member must be recommended by the Council and elected by ballot.

7. A majority of Members present at any Ordinary Meeting shall have the power to expel an obnoxious Member from the Association, provided that a resolution to that effect has been moved and seconded at the previous Ordinary Meeting, and that due notice of the same has been sent in writing to the Member in question within a week after the meeting at which such resolution has been brought forward. The vote to be taken by ballot.

Section IV.

ELECTION OF COUNCIL AND OFFICERS.

The President, Vice-President, Honorary Treasurer, Honorary Secretary, and the six other Members of Council, shall be elected annually by ballot, at the Annual General Meeting to be called in October.

2. The Secretary and Librarian shall be appointed annually by the Council at their first Meeting after Annual General Meeting.

3. Any vacancies occurring in the Council during the year may be filled up by the Council.

4. It shall be the duty of the Council each year to prepare a list containing the names of Members whom they recommend for election, to the respective offices of President, Vice-President, Honorary Treasurer, and Honorary Secretary, together with the names of six other Members whom they recommend for election as ordinary Members of Council. The names thus recommended shall be proposed at one meeting of the Council, and agreed to at a subsequent meeting. Such list shall be suspended in the Association's Room, and a copy shall be sent to each ordinary Member not less than seven days before the day appointed for the Annual General Meeting.

5. Each Member present at the Annual General Meeting shall have the power to alter the list of names recommended by the Council, by adding to it the names of any eligible Members not already included in it and removing from it an equivalent number of names, and he shall use this list, with or without such alterations, as a balloting list at the election of Officers and Council.

6. No ballot for the election of Members of Council or of Officers shall be valid unless twenty members at least shall record their votes.

7. Two Auditors shall be appointed at the Ordinary General Meeting in August or September, who shall audit the accounts and lay them before the Annual General Meeting in October.

Section V.

CONTRIBUTIONS TO THE FUNDS.

1. Each Member shall pay two guineas, and each Associate two guineas, and each Student one half guinea per annum.

2. Every new Member or Associate shall pay an admission fee of two guineas, and every Student shall pay an admission fee of one guinea.

3. All Subscriptions to be payable half-yearly in advance, in the months of April and October.

4. Any Member or Associate whose Subscription is not in arrears, may pay the amount of ten annual payments at any time as a life composition for the ordinary annual payments.

5. Members or Associates whose Subscriptions are twelve months in arrears, will not be entitled to any of the privileges of the Association. The name of any Member or Associate who shall be two years in arrears with his Subscriptions shall be erased from the list of Members and Associates; but such member may be re-admitted on giving a satisfactory explanation to the Council, and on payment of arrears.

6. Every individual elected a Member, Associate or Student, shall be liable for the payment of his Annual Subscriptions, until he has signified to the Secretary, in writing, his desire to resign, having previously paid all arrears, or until he has forfeited his right to remain in, or to be attached to the Association.

Section VI.

THE PRESIDENT.

1. The President shall take the chair at all Meetings of the Association, the Council, and the Committees, at which he is present, and shall regulate and keep order in the proceedings.

2. In the absence of the President, it shall be the duty of the Vice-President to take the chair.

3. In the absence of both the President and Vice-President, the Meeting may elect any Member of Council, or in case of their absence, any Member present to take the chair at the meeting.

Section VII.

THE COUNCIL.

1. The Council to be elected according to the provisions of Section IV. shall consist of the President, Vice-President, Honorary Treasurer, Secretary, Honorary Secretary, and six other members of Council.

2. The direction and management of the concerns of the Association are vested in the Council, under the control of the Act of Incorporation, Rules and By-Laws.

3. The Council shall meet as often as the business of the Association may require; and at every meeting three shall constitute a quorum. The Council may appoint Committees, for special purposes, to report to the Council.

4. The Council shall draw up a yearly Report on the state of the Association, which shall be read at the Annual General Meeting.

5. The funds of the Association shall be lodged at a bank approved of by the Association. Claims against the Association, when approved by the Council, shall be paid by the Treasurer. All payments to be made by cheques, signed by the Treasurer and countersigned by the Secretary.

Section VIII.

THE SECRETARIES.

It shall be the duty of the Secretaries, under the direction of the Council, to conduct the correspondence of the Association; to attend all meetings of the Association, and of the Council, and of Committees; to take Minutes of the proceedings of such Meetings, and all communications that may be ordered to be read; to super-

intend the publication of such papers as the Council may direct; to have charge of the Library; to direct the collection of the Subscriptions, and the preparation of the account of the expenditure of the funds, and to present all accounts to the Council for inspection and approval.

Section IX.

MEETINGS.

1. The Ordinary General Meetings of the Association shall be held on the Second Thursday of each month, subject to alteration by the Council with due notice.

2. At the Ordinary General Meetings the business shall be transacted in the following order, unless the Chairman specially decide otherwise:—

(1) The Minutes of the preceding Meeting to be read, and after having been confirmed, to be signed by the Chairman.

(2) Business arising out of the Minutes to be entered on.

(3) Communications from the Council to be brought forward.

(4) Ballot for the election of new Members.

(5) New Members to enrol their names and be introduced.

(6) Donations to be laid on the table and acknowledged.

(7) Papers to be read and discussed.

3. Every Member shall have the privilege of introducing one stranger, to be present at the ordinary Meetings of the Association, on writing his name in a book provided for that purpose.

4. The Annual General Meeting of the Association shall be held on the second Thursday in October, at eight o'clock in the evening, to receive and deliberate upon the Report of Council with the Annual Statement of the Accounts, and to elect the Council and Officers for the ensuing year.

5. The Council may, at any time, call a Special General Meeting of Corporate Members for a specific purpose relative to the direction and management of the concerns of the Association; and the Council are at all times bound to do so on a requisition in writing of twelve Corporate Members, specifying the nature of the business to be transacted.

6. A notice shall be sent to the Corporate Members at least seven days before the time appointed by the Council for such Special General Meeting, and the notice shall specify the nature of the business to be transacted, and no other than that business shall be transacted at that meeting, and twenty shall constitute a quorum.

Section X.

ENACTMENT OF RULES AND BY-LAWS.

No new Rule or By-Law or alteration or repeal of existing Rules or By-Laws, shall be made unless carried at two successive General Meetings, at each of which twenty members, at least, must be present.

Section XI.

PAPERS AND ORIGINAL COMMUNICATIONS.

1. All Papers and Original Communications must be forwarded to the Secretary, who will lay them before Council; and if approved, notice will be given and the papers read and discussed.

2. Any subject connected with engineering may be brought forward for discussion before the Association provided the Member bringing the matter forward has first asked for and obtained the sanction of the Council.

Section XII.

THE PROPERTY OF THE ASSOCIATION.

1. The property and effects of the Association of what kind soever, are vested in the Corporate Members for the time being for the use of the body politic and corporate solely in furtherance of the public and scientific objects contemplated in the Act of Incorporation.

2. Every Paper, Map, Plan, Drawing, or Model, presented to the Association shall be considered the property thereof unless there shall have been some previous arrangement to the contrary, and the Council may publish the same in any way and at any time they may think proper.

3. The Library shall be open for consultation and for the issue and return of books, subject to such regulations as the Council may deem necessary.

APPENDIX TO THE BY-LAWS.

Form No. 1.

THE ENGINEERING ASSOCIATION OF NEW SOUTH WALES.

Nomination Paper.

Name in full

Designation or Occupation

Business Address

being of the required age, and desirous of admission into the Engineering Association of New South Wales, we, the undersigned, from our personal knowledge propose and recommend him as a proper person to become a thereof. (Member, Associate, or Student to be inserted by proposer.)

Witness our hands this day of 18

PROPOSED BY

SECONDED BY

Five Members' Signatures are required for Member or Associate, and Three for a Student.

Signature of Candidate.

Form No. 2.

THE ENGINEERING ASSOCIATION OF NEW SOUTH WALES.

(Established 1870. Incorporated 1884.)

Sir Sydney, 18 .

I have the honour to inform you that you have this day been elected a of the Engineering Association of New South Wales, and I beg to forward to you a copy of the Act of Incorporation, Rules and By-Laws of the Association.

According to the Rules of the Association you are required as to pay being your admission fee and subscription for the current half-year, and to return the accompanying obligation with your signature within two months of the date of your election, otherwise your election will be void. These conditions being complied with, you will be considered as admitted into the Association, when any publications or notices to which you are entitled will be forwarded according to your directions.

I beg to direct your attention to section V. of the By-Laws, and to point out that all half-yearly subscriptions become due in the months of April and October in each half-year for the half-year then commencing.

I have, &c.,

Secretary.

Form No. 3,

THE ENGINEERING ASSOCIATION OF NEW SOUTH WALES.

I, the undersigned, being elected
of the Engineering Association of New South Wales, do hereby promise that I will be governed by the Act of Incorporation of the Association, and by the Rules and By-Laws of the said Association, as they are now formed, or as they may hereafter be altered, amended, or enlarged, under the powers of the said Act; and I promise to promote the objects of the said Association as far as shall be in my power, and to attend the meetings thereof as often as I conveniently can. Providing that whenever I shall signify in writing to the Secretary for the time being, that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

Witness my hand, this day of 18

Form No. 4.

THE ENGINEERING ASSOCIATION OF NEW SOUTH WALES.

Sydney, 18 .

Sir,

I am directed by the Council of the Engineering Association of New South Wales to inform you that your subscription to the Association is two years in arrears, and in pursuance of Article 5, Section V., of the Rules and By-Laws, the Council have declared by special vote on the
day of 18 , that you have forfeited your claim in future to belong to the Association, and your name will be in consequence expunged from the register unless payment is made previous to

But notwithstanding such forfeiture as regards the future I am directed to call upon you for payment of your arrears, amounting to £

I am, Sir, &c.,

Form No. 5.

Balloting List for the Election of the Officers and Council.

The Engineering Association of New South Wales.

Date

Balloting List for the Election of the Officers and Council.

Present Council.	Names proposed as Members of New Council.	Names proposed by any dissentient Member.
President.	President.	President.
Vice-President.	Vice-President.	Vice-President.
Hon. Treasurer.	Hon. Treasurer.	Hon. Treasurer.
Hon. Secretary.	Hon. Secretary.	Hon. Secretary.
Members of Council.	Members of Council.	Members of Council.

If you wish to substitute any other name in place of that proposed, erase the printed name in the second column, and write opposite to it, in the third, that which you wish to substitute.

OFFICERS, 1885–86.

COUNCIL:

President.

WALTER SHELLSHEAR.

Vice-President.

A. C. MOUNTAIN.

Hon. Secretary.

GUSTAVE FISCHER.

Hon. Treasurer.

JOHN SANDS.

Members.

H. DAVIES.

J. TREVOR JONES.

R. POLLOCK.

H. W. KERLE.

G. A. KEY.

NORMAN SELFE.

Secretary.

W. E. H. NICOLLE.

LIST OF MEMBERS.

NOVEMBER, 1886.

CORPORATE MEMBERS.

1883	Alldjo, L. C.	Mort's Dock and Engineering Works, Balmain
1886	Allen, Percy	Roads and Bridges Department, Sydney
1873	Blacket, Owen ...	Canterbury Engineering Works, Canterbury
1876	Boulton, George ...	Mort's Dock and Engineering Works, Balmain
1878	Bennett, Frank ...	*Evening News* Office, Sydney
1879	Bennett, C.	"Restormel," Darling Point, Sydney
1879	Bailey, W. S.	"Gowen Brae," Cecil-street, Ashfield
1882	Brydon, R.	Chisholm-road, Auburn
1883	Boden, E.	77 Point-street, Pyrmont
1883	Brodie, D....	Harbours and Rivers Department, Sydney
1884	Bush, T. F.	Australian Gaslight Co., Kent-street, Sydney
1885	Bagshawe, F. T. ...	Existing Lines of Railways, Sydney
1884	Burman, E. S.	City Surveyor's Office, Town Hall, Sydney
1885	Briggs, Samuel ...	Mort's Dock and Engineering Works, Balmain
1885	Bergin, F....	Railway Department, Sydney
1870	Cruickshank, W. D.	Marine Board Office, Sydney
1878	Crispin, W.	66 Harbour-street, Darling Harbour, Sydney
1880	Cracknell, E. W. ...	Bond-street Chambers, George-street, Sydney
1883	Cayser, W. J.	Government Tramway Works, Randwick
1883	Darley, C. W.... ...	Harbours and Rivers Department, Sydney
1873	Davies, Hy.	Do. do. do. do.
1870	Davidson, George ...	Messrs. Sutton and Co., Engineers, Brisbane
1883	Dunn, J. M.	Tattersall's Chambers, Hunter-street, Sydney
1883	Diamond, P.	52 Pitt-street, Redfern
1885	De Burgh, E. M. ...	Sewerage Department. Sydney
1886	Duncan, A. J. ...	72 Elizabeth-street, Sydney
1878	Edgington, J.	Atlas Engineering Works, Sydney
1883	Elder, James	"Rocky Glen," Balmain
1870	Franki, J. P.	Mort's Dock and Engineering Works, Balmain
1870	Ferguson, T., senr....	Do. do. do. do.
1874	Ferguson, T., junr.	Colonial Sugar Co., Sydney
1876	Frost, Arthur... ...	Locomotive Engineer's Office, Redfern

1886	Frost, H. P.	587 George-street, Sydney
1882	Fischer, Gustave ...	Existing Lines of Railways, Sydney
1882	Finlayson, R. W. ...	H. P. Gregory and Co., 17 Pitt-street, Sydney
1885	Fitzmaurice, J. S. ...	97 Clarence-street, Sydney
1885	Farmer, W. T.... ...	Sydney Chambers, 130 Pitt-street, Sydney
1885	Formby, M. R.	Looke's Avenue, Balmain
1882	Furness, T. S.	Susan-street, Auburn
1882	Fenwick, J.	Balmain
1885	Ford, H.	Mort's Dock and Engineering Works, Balmain
1870	Grant, W....	Erskine-street, Sydney
1883	Grant, James	3 Point-street, Pyrmont
1885	Grant, J. L.	Harris-street, Pyrmont
1882	Goodall, E. ...	Paul-street, Balmain
1883	Griffin, J. G.	Australian Club, Sydney
1885	Greenwood, W. ...	"Gracombe," Croydon
1885	German, Joseph ...	7 Cohen's Buildings, Spring-street, Sydney
1873	Howe, H. B.	Government Tramway Works, Randwick
1875	Hargrave, L.	Rushcutters' Bay-road, Sydney
1878	Humphreys, W. H....	Bond-street Chambers, George-street, Sydney
1882	Hunt, E. J.	9 Change Alley, Pitt-street, Sydney
1883	Henson, J. B.	City Engineer's Office, Town Hall, Sydney
1883	Henderson, J. B. ...	Water Supply Department, Brisbane
1883	Henderson, T.	
1883	Hudson, Hy.	Clyde Engineering Works, Granville
1870	Hunter, Peter ...	Newcastle S.S. Co., Lime-street, Sydney
1882	Halligan, E. M. ...	Existing Lines of Railways, Sydney
1877	Irons, T.	Atlas Engineering Works, Sydney
1883	Irving, W.	Mort-street, Balmain
1882	Jones, J. Trevor ...	City Engineer, Town Hall, Sydney
1883	Joseph, F. E.	4 O'Connell-street, Sydney
1882	Kingsbury, H. H. ...	54 Margaret-street, Sydney
1881	Kopsch, G. A.	"Saxonia," Boulevarde, Petersham
1883	Kerle, H. W.	141 Pitt-street, Sydney
1884	Kidd, Hector	Colonial Sugar Co., Sydney
1885	Kirwan, M. E.... ...	Box 695, G.P.O., Sydney
1885	Key, G. A....	A.S.N. Co.'s Works, Pyrmont
1885	Kendall, Robert ...	Existing Lines of Railways, Sydney
1870	Laing, J.	Snail's Bay, Balmain
1881	Lewin, A. J.	Albion Engine Works, Balmain
1885	Leahy, J. A. L. ...	17 Macquarie Place, Sydney

1883	Mountain, A. C. ...	City Surveyor, Town Hall, Sydney
1870	Morell, G. A.	156 Pitt-street, Sydney
1876	Mainwaring, M. ...	Austral Foundry, Pyrmont
1879	Moore, F.	Existing Lines of Railways, Sydney
1881	Morse, R.	Rockdale, Illawarra Railway
1883	Mackay, Angus ...	Technical College, Sydney
1883	Milne, W....	Sussex-street, Sydney
1881	McPherson, H. ...	491 Kent-street, Sydney
1877	McCredie, A.	20 Wynyard-street, Sydney
1882	McCredie, G.	20 Wynyard-street, Sydney
1885	Macfadyen, J. J. ...	Botany Waterworks
1885	Macdonald, A. B. ...	3 Paul-street, Balmain
1885	Massey, G.	Foy's Chambers, Bond-street, Sydney
1875	Nicolle, W. E. H. ...	Harbours and Rivers Department, Sydney
1877	Nelson, A. D.	Hay-street, Darling Harbour, Sydney
1886	Noakes, W. M., ...	43 York-street, Sydney
1886	Nixon, E. S.	34 Jamieson-street, Sydney
1883	O'Neil, C....	200 Cumberland-street, Sydney
1873	Perdriau, H.	Balmain Engineering Works, Balmain
1878	Patterson, J. J. ...	Brumby-street, Strawberry Hills, Sydney
1881	Parry, John	Existing Lines of Railways, Sydney
1878	Pollock, Robert ...	Bulli Coal Co., 17 Bridge-street, Sydney
1873	Proctor, J.	19 George-street, Redfern
1870	Poolman, S.	Colonial Sugar Co., Sydney
1882	Parrot, T. S.	Mercantile Chambers, Pitt-street, Sydney
1883	Preston, J. B.	14 Castlereagh-street, Redfern
1885	Parkinson, W. A. ...	"Arthursleigh," William-street, Randwick
1886	Paisley, W.	Burwood
1884	Richmond, J.	Messrs. John See and Co., Sussex-street, Sydney
1886	Ritso, G. F.	G.P.O., Sydney
1886	Rhodes, Vincent ...	Clyde Engineering Works, Granville
1886	Robertson, W. F. ...	335 Pitt-street, Sydney
1870	Scott, W.	Gov. Railway Works, Redfern
1873	Scott, R.	Gov. Railway Works, Redfern
1875	Scott, J.	24 Shepherd-street, Darlington
1885	Scott, T.	Orient S.S. Co.
1870	Selfe, Norman ...	Lloyd's Chambers, George-street, Sydney
1882	Selfe, Hy....	Marine Board Office, Sydney
1878	Smith, H. Shaw ...	17 Pitt-street, Sydney
1881	Smith, T. F.	Robinson-street, Croydon
1873	Sands, John	Albion Engine Works, Pyrmont
1878	Sands, H. G.	"Marmion," Waverley
1882	Schulze, Oscar ...	313 Kent-street, Sydney
1881	Shellshear, W. ...	Existing Lines of Railways, Sydney
1882	Stewart, T.	Electric Telegraph Department, Sydney

1883	Stone, J. J.	Harbours and Rivers Department, Sydney
1883	Smyth, S.	"Ashton," Waverley-street, Waverley
1884	Stables, E. C.	New Zealand Sugar Co., Auckland, N.Z.
1884	Smail, J. M.	Sewerage Department, Sydney
1885	Shaw, P. W.	Existing Lines of Railways, Sydney
1879	Thomson, Max	Existing Lines of Railways, Sydney
1885	Thomson, J. R. ...	Atlas Engineering Works, Sydney
1882	Townsend, G. W. ...	Colo Valley via Richmond, N.S.W.
1873	Tipping, J.	Government Railway Works, Redfern
1882	Tulloch, R.	Phœnix Works, Pyrmont
1882	Toyer, A.	Daily Telegraph Office, King street, Sydney
1885	Touch, J. E.	Existing Lines of Railways, Sydney
1883	Van de Velde, C. ...	Royle's Chambers, Bond-street, Sydney
1886	Vale, Hy. J.	Locomotive Works, Auburn
1878	Wilson, W. G.... ...	Snail's Bay, Balmain
1878	Wildridge, J.	Messrs. Gibbs, Bright and Co., Pitt-street, Sydney
1881	Wright, John	Railway Department, Sydney
1882	West, W.	Balmain Engineering Works, Balmain
1882	Walker, John	H.M.C.S. "Wolverene"
1883	Walsh, Fred	51 Hunter-street, Sydney
1883	Waugh, D.	Brisbane-street, Sydney
1884	Warren, W. H. ...	Sydney University
1885	Wells, W. S.	Roads and Bridges Department, Sydney
1886	Watkins, C. E. ...	Reefton, New Zealand
1886	Wilkinson, C. S. ..	Mines Department, Sydney

STUDENTS.

1884	Burrows, C.	Albion Engine Works, Pyrmont
1886	Edgell, R. G.	Mort's Dock and Engineering Works, Balmain
1882	Laidley, R.	W. Laidley and Co., Exchange, Sydney
1884	Moffitt, W.	Locomotive Engineer's Office, Redfern
1885	Moore, G. E.	Albion Engine Works, Pyrmont
1882	Nicolle, E. H. S. ...	Mort's Dock and Engineering Works, Balmain
1883	Stokes, S.	Drayton House, Leichhardt
1883	Woolnough, H. B. ...	Mort's Dock and Engineering Works, Balmain

HONORARY MEMBERS.

Broderick, Hy. ...	Sydney Club, Castlereagh-street, Sydney
Bennett, W. C. ...	Engineer-in-Chief for Roads and Bridges, Sydney
Barnet, James... ...	Colonial Architect, Sydney
Cracknell, E. C. ...	Superintendent Electric Telegraph Department, Sydney
Jacob, A. H.	Ashfield
Moriarty, E. O. ...	Engineer-in-Chief for Harbours and Rivers, Sydney
Poole, W. T.	Hampden House, Pitt-street, Redfern
Sutherland, John ...	Abercrombie-street, Sydney

THE ENGINEERING ASSOCIATION

OF

NEW SOUTH WALES.

SESSION—1885-86.

MINUTES OF PROCEEDINGS,

8TH OCTOBER, 1885.

HENRY DAVIS, PRESIDENT, in the Chair.

THE following candidates were balloted for, and duly elected as

MEMBERS.

GEORGE MASSEY,
JOHN E. TOUCH,
JAMES T. FITZMAURICE,
JOHN A. L. LEAHY.

The SECRETARY read the Annual Report of the Council, and the Balance Sheet for the year ending 30th September, 1885, as follows :

"The Council have the pleasure of presenting to the members on this occasion of the fifteenth anniversary of the Association the following Annual Report for the past year :—

"The number of members continues to increase, there having been added to the roll during the past year eighteen corporate members and three students ; whilst four members have resigned, and three members and one student have been erased from the books. The number of names at the 30th September was 140 in all ; being 123 corporate members, nine students, and eight honorary members.

"The accounts for the year having been duly examined by the appointed auditors, are now submitted for the information of members. It will be seen that the expenditure has this year exceeded the income by £49 12s. 3d., the actual income (less the amount transferred from the late exhibition trust fund) being £315 5s. 11d., whilst the expenditure amounted to £364 18s. 2d. This excess is accounted for by the fact of having to pay a very high rental for the meeting rooms, and also the irregularity of the payment of subscriptions by members.

"A balance-sheet is also submitted, showing the financial position of the Association at the end of the year to be in a satisfactory state. The total investments and other assets amounted to £831 7s. 2d., and the liabilities being nil, the same amount constituted the capital of the Association at the end of the financial year.

"The following papers were read during the year at the regular general monthly meetings, viz. :—

"In December, 1884, by Mr. G. Fischer, on the 'Pneumatic System of Sewerage,' the discussion of which occupied the following general meeting in January.

"In February, by Mr. H. W. Kerle, on 'Improvements in Hydraulic Lifts.'

"In March, a contributed paper by a non-member, Mr. F. Bergin, on 'Graphic Statics,' a subject which was further discussed at the April meeting.

"In May, two papers were read. The first, by Mr. D. Waugh, no 'Mechanical Dairying Appliances;" and the second, by Mr. W. Shellshear, on the 'Coast Defences.'

"In June, by Mr. J. W. Rock, on the 'Connection of Sydney with North Shore by a Tunnel.'

"In July, by Mr. G. Fischer, on the 'Inoffensive Destruction of Nightsoil and City Refuse.'

"In August, a paper contributed by Mr. E. C. Wood, a non-member, on 'Continuous Girder Bridges,' which, in the absence of the author, was read by Professor Warren.

"And in September, a paper was read by Mr. H. W. Kerle on 'Flour Mill Machinery.'

"The Council, in the early part of the year, formulated a circular containing a list of suggested subjects for papers, copies of which were distributed to each of the members and also several non-members, specially inviting them to contribute orginal papers for reading at the general meetings, and for constituting an annual volume. Two non-members, as already stated, very kindly responded to this invitation, both contributing interesting and valuable papers; though, amongst the members, very little notice appears to have been taken of this appeal. It is a matter for regret that the efforts of the Council have been attended with so little success, and that the members show so much antipathy to writing papers, especially papers on mechanical subjects, which of late have been the exception; and considering that twelve papers only are requisite to occupy the regular meetings (though

more could be dealt with), it is somewhat surprising that there is so much difficulty in inducing twelve different members to contribute this number. It is to be hoped that during the ensuing year members will interest themselves more for the common benefit of the Society, and endeavour to overcome this very apparent antipathy, so that a volume of respectable proportions may be produced at the end of the year.

"During the year several excursions were made to various works of professional interest, the first of which took place on the 11th of October, 1885, and was to view the works on the Illawarra railway line, then just completed, and about to be opened as far as Hurstville. The members, numbering about 70, proceeded by special train to George's River, and there viewed the fine iron bridge then in course of erection, and a most profitable and pleasant afternoon was spent. On the 11th of July the Association was invited to view the Bondi section of the sewer and outlet works. About 50 members attended, and were courteously conducted by the departmental and contractors' engineers over the whole of the works, and a satisfactory afternoon was passed. On the 22nd of August the Association was invited to visit the temporary Water Supply Works, then being constructed by Messrs. Hudson Bros. About 50 members proceeded by train to Guildford, where they were met by the Messrs Hudson, and conducted along the fluming which is to convey the water from the end of the canal to the pipes which lead to the Botany dams. And on the 12th of September the members visited the works of Messrs. Hudson Bros. at Granville, for the purpose of seeing the wrought iron pipes being manufactured for the temporary Water Supply Works. On both occasions those present were much interested in the work, and well satisfied with their outing.

"At the July general meeting it was resolved to again remind the Government of the promised Patent Bill, a draft of which had been prepared by the Association, in conjunction with other societies, in 1883, and which had been presented by a deputation to the Colonial Secretary, who promised to introduce a new bill. Accordingly, a petition to Parliament was prepared, praying for a speedy amendment of the present Act, and, after having been signed by the majority of the members, was presented to the House by Mr. Garrard, M.L.A. Unfortunately, the sudden termination of the Parliament again extends the opportunity for introducing the measure, the want of which is so much felt in the inventive community.

"At the general meeting, in August, a resolution was passed that this Association hold an exhibition of Mechanical and Scientific Appliances and Inventions, in the year 1886. A committee was formed, and a deputation waited upon the Mayor of Sydney, to request him to grant the free use of the Exhibition Building, at Prince Alfred Park, from the 15th of July to the 30th of August, 1886, for the purpose, which he very kindly assented to, and a formal application to the Municipal Council being necessary, the same was duly forwarded. An executive committeee has been appointed to make all necessary arrangements, and it is hoped that every member of the Association will render whatever assistance they are able, to bring about a successful issue.

"The Council have awarded the gold medal for the year to Mr. G. Fischer, for his valuable contributions on "Sanitation," and have also awarded a silver medal to Mr. F. Bergin, for his paper on "Graphic Statics."

"In conclusion, the Council desire to express their thanks to those members who have contributed papers during the year, and also to those who have attended the meetings for the purpose of discussion, and trust that the ensuing year will see the Association still more prosperous."

ENGINEERING ASSOCIATION OF NEW SOUTH WALES.

Cr. BALANCE SHEET as at 30th September, 1885. **Dr.**

APPROXIMATE.

By Cash—	£ s. d.	£ s. d.
In E. S. and A. C. Bank on Deposit	306 0 0	
Do. do. Current Account	138 1 5	
		444 1 5
,, Subscriptions in Arrear		65 13 3
,, Annual Reunion ,, ...		11 12 6
,, Library, Drawings, Proceedings, &c....		250 0 0
,, Furniture and Fittings...		60 0 0
		£831 7 2

	£ s. d.
Capital of the Association at this date...	831 7 2
	£831 7 2

(E. and O.E.) Audited and certified by,—

J. B. HENSON.
FRED. WALSH.

ENGINEERING ASSOCIATION

Cr. *Accounts of Receipts and Expenditure*

RECEIPTS.	£ s. d.	£ s. d.
By Entrance Fees—		
17 New Members, at £2 2s.	35 14 0	
3 Students, at £1 1s.	3 3 0	
1 Member's Fee, elected in 1884 ...	2 2 0	
1 do. do. ...	0 10 0	
		41 9 0
,, Annual Subscriptions		125 0 9
,, Annual Reunion		83 6 0
,, Rent of Rooms		31 3 4
,, Excursion Subscriptions		2 15 0
,, Sale of Pamphlets		1 9 6
		285 3 7
,, Exhibition Trust Fund	404 0 0	
Less Expenses	99 0 1	
		304 19 11
,, Bank Interest		30 2 4
Total Receipts		620 5 10
,, Cash Balance 30th September, 1884 ...		188 13 9
		£808 19 7
Cash Balance at this date	444 1 5	
		£444 1 5

OF NEW SOUTH WALES.

for the year ending September 30th, 1885. **Dr.**

EXPENDITURE.	£	s.	d.	£	s.	d.
To Annual Reunion...				85	6	0
,, Rent of Rooms				102	15	5
,, Printing Pamphlets—						
On Water Carriage System of Sewerage	12	5	0			
On Lieurner Sewerage System ...	8	15	0			
On Graphic Statics	19	2	6			
On Destruction of City Refuse ...	9	7	6			
				49	10	0
,, General Printing and Binding ...				24	0	6
,, Periodicals and Proceedings				23	3	2
,, Property—						
Corporate Seal and Press	10	3	0			
Reading Stand	3	0	0			
				13	3	0
,, Excursions				9	12	6
,, Petty Cash, including Stationery, Postage, &c.				23	6	2
,, Secretary's Allowance				25	0	0
,, Prize Gold Medal				5	5	0
,, Exchange and Sundries				1	15	2
,, Interest on Current Overdraft ...				2	1	3
Total Expenditure ...				364	18	2
,, Balance—Fixed Deposit	306	0	0			
Current Account	136	17	2			
Cash in hand	1	4	3			
				444	1	5
				£808	19	7
Cash Balance 30th September, 1884 ...	£188	13	9			
Balance brought down	255	7	8			
				£444	1	5

Audited and certified by— J. B. HENSON,
FRED. WALSH.

The Report and Balance Sheet were unanimously adopted.

The ballot for the election of officers and members of Council for the session 1885–86 resulted as follows:—

PRESIDENT:
WALTER SHELLSHEAR.

VICE-PRESIDENT:
ADRIAN C. MOUNTAIN.

HON. SECRETARY:
GUSTAVE FISCHER.

HON. TREASURER:
JOHN SANDS.

OTHER MEMBERS OF COUNCIL:

PROFESSOR W. H. WARREN.	JOHN TREVOR JONES.
HENRY DAVIES.	ROBERT POLLOCK.
H. W. KERLE.	NORMAN SELFE.

The Council of the Association having awarded the gold and silver medals to G. Fischer and F. Bergin respectively, the former for his papers on "Sanitation," and the latter for his paper on "Graphic Statics," the medals were presented by the President.

MINUTES OF PROCEEDINGS.

12th NOVEMBER, 1885.

Walter Shellshear, President, in the chair.

The following candidates were balloted for and duly elected as

Members:

THOMAS SCOTT.
E. M. De BURGH.

Mr. Walter Shellshear addressed the meeting in the following terms on taking the chair at the first meeting, after his election as President :—

Gentlemen,—My first duty in assuming the chair to-night is to thank you for the distinguished honour you have conferred upon me by electing me your President. The office is, indeed, one of some distinction, and one which any gentleman might feel honoured in fulfilling ; and so much do I appreciate the dignity and the responsibilities of the position that I promise that, while I occupy this chair, my best endeavours shall be exerted to disseminate a knowledge of the Society's existence and worth, and to increase its prosperity and usefulness. I feel that it will be a pleasant and easy duty to uphold the position you have placed me in, for I feel assured that your hearty support will always be accorded in promoting the harmony and interest of the meetings. I trust that during my tenure of office there will be no dearth of contributions by the members on subjects of interest connected with our profession, as it is to Associations of the character of our own that the public look for information on all matters connected with the rapid development of engineering science. I propose briefly to consider our position as an Association, and the great future that is before the profession in developing the vast resources of this rich land.

The Association was established in October, 1870, and in 1871 the number of members did not amount to more than sixteen, but it is gratifying to find that even with this small beginning the Association was not without its influence in imparting good to the profession. At that time the rising generation of engineers in Sydney were without any of the advantages which the junior members of the profession now

enjoy by the recent establishment of the Technical College and kindred institutions, and but for the instruction imparted by the pioneers of this Association they were practically without teachers. The energy and devotion with which the promoters worked in imparting useful knowledge, especially to the younger members, is worthy of all praise, and the name of our worthy past-president, Mr. Cruikshank, will long be remembered by the mechanical engineers of Sydney, for his disinterested services in the cause of Australian engineering. In its early days the Association performed much of the work which is now being so well done by the Technical College, that useful institution being brought into existence mainly by the exertions of the members of this Association, and at the present time Sydney is as well provided with the means of imparting technical knowledge as the majority of towns in the older countries of the world of a corresponding size and importance. The instruction given at the engineering classes of the University and Technical College is of a most useful character, and well calculated to lay the foundation of a substantial engineering education.

Within late years the colony has progressed by leaps and bounds, the comparatively insignificant engineering works that were in progress at the time of the foundation of this Association have been succeeded by vast undertakings, and, in proportion to the population, I believe a larger amount of engineering work is going on in this colony than in any other part of the world. These works necessitate the employment of many members of our profession, and it is daily becoming more manifest that the system of centralization which now obtains must give place to local boards of works. The necessity and importance, therefore, of this Association as the representative body of the profession in the colony must daily increase, and it may be well to remind the members that much of the success and harmony that exists among the leading engineers in England is due to the friendly relations established among the members of the profession by the skilful and energetic labours of the leading members of the great Institution of Civil Engineers. Following the example of that great body, it should be the constant endeavour of the members of this Association to establish a like good feeling and friendly co-operation among the members of the profession resident within the colony, and it is to be hoped that the day is not far distant when our ranks shall include all the members of the profession in our colony, and our position be fully recognised by all kindred institutions in the world.

By an Act of Incorporation granted by Parliament last year, this Association moved out of its former position of comparative obscurity to one of recognised publicity, and it is incumbent upon us to show to the public that the Association was worthy of this recognition.

During the past year many useful and interesting papers have been presented to the Association and read before the meetings, copies of which have been circulated among the members, and I am hopeful that by the end of this year we shall find ourselves in a position to be able to publish an annual volume worthy of the Association. I have in connection with this but to express a hope that the members will furnish papers and other useful information to enable our Honorary Secretary to have ample material upon which to show his ability as an editor.

THE COMING EXHIBITION.

The next matter which I desire to bring prominently before you is our proposed Exhibition, and this is an adjuuct of the Society's business which may do much if properly carried out to give the public a knowledge of its existence and its usefulness. Judging from the experience of the past, our labours, if properly directed, should be crowned with success, and it should be the endeavour of all to make the exhibition a credit to the Association. We shall have an opportunity by this means of showing many of the latest inventions in electricity and science. One great aim of the Association should be to see that the colonial manufacturers are well represented, and I think if this be done we shall be able to show that New South Wales is able to hold her own in the march of engineering science, and in the production of many articles of commerce. The thanks of the Association are specially due to the City Council for their great liberality in placing the Exhibition Building at our disposal for the exhibition, thus showing their sympathy with us and giving a substantial earnest of public support.

In previous years we have had opportunities from time to time of visiting various works in progress, and I consider these outings of great importance in helping the advancement of the Association, as on these occasions members not only have an opportunity of seeing much that is interesting, but they bring them together in friendly and social intercourse which is not at all times possible by a mere attendance at the monthly meetings. They further promote friendly discussions on

matters of congenial interest, and generally result in the acquisition of new found knowledge. There are several works now in progress near the city which it is to be hoped we may have an opportunity of visiting during the year, among which may be mentioned the new dock at Cockatoo Island, the railway workshops, Eveleigh, the Gasworks, the syphon for the main southern sewer under the Cook's River, and other important works.

Of our last year's outings, our visit to the main outlet sewer, Bondi, was perhaps the most interesting from a civil engineer's point of view, and I am sure all the members who visited these important works must have been struck with the high class of material and workmanship used in their construction. Although I have seen many works of the same class in the old country, I must confess I have never seen more substantial and really creditable work. Our mechanical engineers have great cause for congratulation. The ingenuity of the mechanical appliances designed and brought into use by Messrs. Hudson Brothers for the manufacture of wrought iron pipes for the temporary water supply are deserving of special notice, and every member who recently visited the works at Clyde with the Association, must have been greatly impressed with what they saw; the works being not only a credit to the proprietors but a decided step in the progress of colonial enterprise.

ENGINEERS UNDER LOCAL GOVERNMENT BOARDS.

Now that the question of Local Self-government is under discussion, a few remarks on the subject as affecting our profession may not be out of place. Perhaps there is no better example of the success with which the system of Local Self-government can be carried out under skilful oversight than is to be seen in the management of the river Clyde in Scotland. The works that have been carried out in improving this river are a master-piece of engineering. Although unlike the rivers of this colony, the Clyde was not obstructed by a shifting bar, yet at the beginning of the present century the river was little better than a ditch, which could be forded with ease at several points, at low tide. By the patient labours of the engineer this state of things has changed, and where this river could be forded only a few years back, there is a sufficient depth of water to float the "Austral." Up to 1883 £9,908,592 had been expended on these improvements, but the revenue had more than kept pace with the improvements. In 1800 the revenue amounted

to the insignificant sum of £3,319 16s. 4d., but in 1883 it was no less than £283,998 8s. 5d., and so well has the financial part of the business been managed under the local self-governing body, the Clyde Trust, that although they have expended the large sum just mentioned, their debt in 1883 was only £4,259,685, or considerably more than half the money that had been spent on improvements has been derived from the revenue resulting from the improved trade brought about by the altered condition of their river and the development of ship building and other manufactories. The Commissioners for the river Tees have been equally successful in the management of their river, and their finances are also in a very sound condition.

It is to be hoped that when the various shires are formed under a Local Government Act, that the shires may be of sufficient extent to enable the boards to pay a competent engineer, and that a similar system of examination as to qualifications of shire engineers may be established to that in vogue in Victoria.

IRON *v.* WOOD FOR BRIDGES.

The present low prices of iron and steel afford a good opportunity of extending their use in the construction of bridges and other permanent works where timber has previously been in use; in places with easy access the difference in prices is insignificant, and in a climate like that of New South Wales the life of an iron structure (where not erected within the influence of the sea) if a reasonable amount of care be taken with it, would be many times greater than that of timber, and whereas the condition of a timber structure is at all times doubtful when decay, or the inroads of white ant has once set in, in the case of an iron structure its condition can be seen by ordinary inspection, as any defects at once become apparent.

METALIC PERMANENT WAY.

Steel sleepers are coming largely into use on the Continent and in England, the London and North Western railway has laid down many miles of road with steel sleepers, and are still extending their use. In parts of the colony where timber is scarce or unprocurable, except from long distances, steel sleepers could probably be supplied at the same price, if not somewhat cheaper than timber, and would be more durable.

WATER CONSERVATION.

Much has been written and said on the subject of the conservation of water, and this opens up a most extensive field for the operations of the engineer. In time to come Australia will require very extensive irrigation works for its development. At present much could be done to alleviate the effect of droughts by the construction of tanks, and improving the arrangements for watering stock at existing creeks and water holes. During a recent visit to the Richmond River district I came across large numbers of cattle dead and dying at the various water holes; the water being low in the holes, the cattle became bogged in attempting to reach it. This evil might have been avoided if suitable approaches to the water had been made, which could have been done by the expenditure of a small amount of labour in drawing branches of trees and scrub to the holes. Those who take a special interest in this subject should read Mr. W. E. Abbott's paper on "Water Supply in the Interior of New South Wales," read before the Royal Society; this paper is of great value, as it deals with the subject in a really practical way.

MINING.

The sudden development of silver mining in the colony marks an era in its history, and goes to show how limited our knowledge of the mineral resources of the colony is at present. I hope that the Association may be favoured with some valuable papers on the subject of silver mining and the treatment of its ores, at an early date, as, no doubt, some of our members are largely interested in this new development of the colony's wealth. The depreciation in the value of copper is a very serious blow to the producers of that metal in the colony, and I am glad to be able to inform the members that a paper has been promised for the next meeting describing a new method of treating copper ore, and one that bids fair to revolutionize the whole process of manufacture, and which I hope may be a great help to the copper industry of the colony, as by this process the cost of treatment promises to be but a fraction of the present cost of production, and may possibly, if introduced, make all the difference between a paying concern and a losing one for those interested in the industry. Although the present low price of copper is a misfortune to the copper industry of the colony, it should have the effect of extending the use of the alloys of copper, especially manganese and phosphorus bronzes, these materials offering a practical solution of

the question of preventing the rapid corrosion which takes place in torpedo boats and light steam launches when made of steel, whereas if made of the above alloys the rapid deterioration would be avoided.

With the exception of the single blast furnace at Eskbank, the manufacture of iron in the colony is so far undeveloped, and through the want of skill in dealing with our iron ores at Mittagong, the erroneous impression has gone forth that there is something peculiar about the iron deposits of the colony. The ores of iron found in the colony are mostly brown hœmatite, a somewhat refractory ore, but one that has been largely used in other parts of the world, and with suitable furnaces there is no reason why first-class iron and steel could not be made in the colony. The question of making it at a profit with the present low prices is doubtful, but local ironworks would be of inestimable value in the event of an extensive naval war, when the free passage of ships would be obstructed. It is to be hoped that when another attempt is made to develop this industry it will be done on a scale of more magnitude than has hitherto been the case, and that plant suitable for hœmatite smelting will be used instead of the smaller type of furnaces generally used for less refractory ores.

OUR RAILWAYS.

The colony may be justly proud of the rapid development of its railway system, and a few facts relating to the advance of this public work since the foundation of the Association may not be out of place. At the close of 1870 there were only 339 miles of line open for traffic ; the number of passengers carried for the year was 776,707, and 117,854 tons of goods were carried, with the unsatisfactory result that the lines only paid 1.817 per cent. on the capital invested. At the end of 1884, 1,618 miles of line were opened for traffic ; the number of passengers carried was no less than 11,253,109, and 3,124,425 tons of goods were carried, and the lines paid 4.201 per cent. on the capital invested. Thus in the short space of 14 years the passenger traffic has increased something over twelvefold, and the goods traffic nearly thirtyfold, and this great advance has been secured at such a reasonable figure that the lines now pay a fair dividend on the capital invested, to say nothing of the enormous gain of wealth that the railways have brought about in the development of our otherwise practically inaccessible back country.

The progressive development of the country must mainly depend on the extension of the railway system, and if part of the increased value of the land resulting from the construction of the railways was set off against the capital account, the burden of interest would be so far reduced that lines could be worked in many localities where, according to the present system of keeping the land accounts separate from the railway, or, what is worse still, letting the land near the lines be taken up at a nominal price immediately before the lines are constructed, the profits resulting from the improved communication go into private pockets instead of that of the State, and the lines can then only be worked at a loss. The land grant system of constructing railways has been largely in vogue in America, and has been proposed in some of the colonies. Although this system has its drawbacks, there are many points about it that could be adopted with advantage in the development of State railways. By resuming a certain proportion of the land along the proposed lines of railway, and disposing of it as a set off against the capital cost of the line after the railway has been open for traffic, not only would the country be opened up, but the indebtedness of the community would be kept down, and the evil day of taxation avoided.

THE CITY RAILWAY.

The question of extending the railway into the city is becoming more urgent, the capacity of the trams being so far taxed that every day the necessity of this important work becomes more apparent. In looking round at what has been done by our neighbours in the way of developing suburban railways, we have an example that is worthy of imitation, for with the Melbourne system of suburban lines the population is able to spread over a large area, and instead of the unsatisfactory and unhealthy terrace houses so largely in vogue in the suburbs of Sydney our neighbours have allotted a respectable block of land to most of their houses, and every man if he likes can live under his own vine and fig tree. Not only are suburban lines a great boon to the public, but as the suburbs develop they afford most remunerative traffic for the railway proprietors.

STREET PAVING.

Having thus briefly referred to the proposed extension of the railway into the city, there is a matter in connection with recent city improvements that deserves notice. I refer to the great improvements

that have been made in the principal streets within the last few years. I consider the wood paving a great credit to the city, and their general appearance and the excellent way they have been laid will compare most favourably with any other street paving I have seen in the old country. It would be difficult to find a better paving material than the hardwoods of the colony

THE TRANSIT AND PRESERVATION OF MEAT.

The supply of the city with good meat is a matter that, in my opinion, has not received the attention it deserves, and I think that a very wide field is open for the inventive genius of our members in connection with the perfecting of refrigerating plant for the carriage of dead meat over long railway journeys, and in this matter the best road to success can only be by the co-operation of the various parties interested in the trade, both in town and in the country. I feel sure that with proper arrangements, the whole of our meat supply could be procured from the country ready butchered, in a much better condition than at present, even in the hottest weather, and not only would the cattle and sheep be spared the painful journey, but the trade could be conducted with greater profit to all parties concerned, as with proper chill rooms, the large amount of waste in the hot weather could be greatly reduced, and the meat being in a better condition would command a higher price, and consequently a better profit to those engaged in the trade. In England and America great attention is now being paid to the storage and transit of frozen meat, and with the improved facilities the supply can be regulated to suit the demand. The meat trade should also be a great source of wealth to the coast districts, if the coasting steamers were fitted with freezing chambers, and proper frozen meat stores were erected in Sydney.

RIVER IMPROVEMENTS.

I am afraid I have nearly exhausted your patience, but before concluding, I desire to say a few words regarding our eastern rivers. With our dry and uncertain climate, the extent of country available for agriculture is limited. With the exception of the coast district, the rainfall is so small and irregular that agriculture must of necessity be very precarious until some system of irrigation is developed. The fertile areas of the coast districts may therefore be considered the garden of the colony, and the development of these deserves more attention than they have as yet received. I recently visited the Richmond River

district, and was more than surprised at the vast extent of splendid country in crossing what is called the big scrub, which extends from the Richmond River to the Queensland border. There is an almost uninterrupted stretch of country, the soil of which is of the richest possible description. The natural vegetation is so luxurious and beautiful that a student of botany could almost imagine himself in an ideal paradise. The soil is a black volcanic earth derived from the decomposition of the basalt, and in most parts is of great depth. The agriculture of the district is mostly confined to sugar-cane and maize, which grows most luxuriously both in the volcanic soil and also on the alluvial flats of the river. But there can be little doubt that the country is suitable for the growth of many other products which in time to come will be one of the greatest sources of wealth to the colony. The alluvial flats of the Clarence are equally fertile, and I believe that the other eastern rivers have also large extents of equally valuable land, but as you all know the entrances of these rivers are all more or less obstructed with dangerous sand bars which are a constant source of vexatious delays and dangerous to those who trade with these otherwise splendid districts. Almost from the time I landed in the colony I have taken a deep interest in the problem of how this difficulty could be overcome, and in the study of the question I have collected information as to what has been done in all parts of the world. The result of these inquiries has been embodied in two papers, one of which I recently forwarded to the Institution of Civil Engineers. If it were not for the fact that the Government had been fortunate enough to secure the services of Sir John Coode to report on the subject I should probably have devoted much of this address to the consideration of the question, as I consider it one of the greatest importance to a large section of the public, but I will merely say that I am convinced that safe entrances can be secured to all the principal rivers at a moderate cost, by the execution of judiciously planned works, and I think the colony has great reasons for congratulation that Sir John Coode has had an opportunity of reporting on the subject, for, judging from his various published reports and speeches, there can be no doubt that by the same consistent application of sound principles that has brought this great engineer into his present high position, these barriers, which many sages have said could not be removed, will ere long be a thing of the past, and we may look forward with confidence to the speedy removal of the great obstacle in the way of the advancement of the rich coast district.

In conclusion, it is to be regretted that the importance of the work of the engineer is not better appreciated, and also that the vastness of the field of knowledge which embraces the science of engineering is not better understood. We find members of the medical profession doing well, the legal profession on all sides making a fat living, and yet the services of the engineer are so highly valued that a year or two back, when discussing the estimates in Parliament, no less than three hours were employed on the question of an increase of £50, which was placed on the estimates for an engineer having an important and responsible position in one of the departments, and whose salary, I believe, was the munificent sum of £350 per annum, and yet the same night a vote of £1,500,000 was passed in a few minutes, only one member thinking it worth his while to speak on the subject. It is to be hoped that under a good Local Government Bill the profession may be better appreciated.

There are two passages from recent speeches that I think worth quoting for the informatian of those who consider it possible for one man to know everything in connection with the science of engineering, from turning a $\frac{5}{8}$ bolt to building a harbour; and to show how small their comprehension of the vastness of the subject is, I refer to this passage from the President's address recently delivered before the Institution of Mechanical Engineers. Mr. Head says :—"In the earlier days of engineering it was possible every few years to give with some approach to completeness, and within the limits of an address, a more or less complete *résumé* of the past, a description of the present, and an indication of the future. The immense developments, however, of the applied science in recent years has made this increasingly difficult. No one can now do more than aim at 'knowing something of everything, and everything of something.' I say 'aim at' because attainment of perfection in the narrower sphere, and of universality in the wider, is equally impossible. The great mass of technical literature published nowadays, which inevitably and punctually arrives to flood the office of every known engineer, is almost bewildering, The supply of information and facilities for circulating it seem to be fast getting out of proportion to the time, the brain power, and the eyesight of the most energetic readers. The book-shelf, and even the waste paper basket, are, I fear, too often or too immediately, the sources of relief. Many a paper, article, and book has to be put aside with a sigh till a more convenient season, which perhaps never arrives ; and so it comes that every engineer must feel more and more as he grows older that he knows but very little even of his own profession."

The second passage is Sir John Coode's reply when asked to report on the water schemes by the Government regarding the Prospect and Kenny Hill scheme. Sir John said :—"That with regard to this particular water scheme, he thought it was a question upon which great divergence of opinion existed, and one which—with even more time at his disposal than he had—would require closer attention than he was prepared to give to it. There was a still stronger reason which prevented him from taking up such an inquiry. He was, like most other men of his profession, a specialist, and during the past forty years and more his attention had been almost entirely devoted to harbours and rivers. Therefore, he would hardly feel disposed, in any circumstances, to undertake such an inquiry."

The question that naturally arises from the above expressions of two of the greatest engineers of the day is :—Can the public of New South Wales reasonably expect that with the present system of centralization it is possible for two or three engineers, however experienced, competent, and well-informed they may be, to grasp and enter into even the general scope of the vast undertakings that are necessary for the development of this noble colony ? or would it not be more in accord with common sense, economy, and advancement, to institute a good comprehensive system of Local Self Government under the management of those who profit by or lose by the judicious or injudicious expenditure of public money in their district ?

Finally, before resuming my seat, I cannot refrain from impressing upon members the great benefits that accrue from an Association such as ours, where many minds are concentrated on any one given subject, and where they have the opportunity of giving expression to their opinions on any matter affecting the engineering world. We should always remember that :—

> "It is by mutual intercourse and mutual aid
> Great deeds are done and great discoveries made."

MINUTES OF PROCEEDINGS,

10th DECEMBER, 1885.

Walter Shellshear, President, in the chair.

The following candidates were balloted for and duly elected as

Members:

HENRY E. DICKENSON.
FRANCIS BERGIN.
JOHN McDOUGALL.

Mr. Clement van de Velde then read the following papers :—

THE TREATMENT OF COPPER ORES

BY THE

"MANHES PROCESS."

By CLEMENT VAN DE VELDE.

In late years very rich copper fields have been discovered in various parts of the world, and at many of the mines worked, principally in the United States of America, an enormous production is the result, and to-day, copper, like many other staples, is produced more than the demand requires. The latest statistics show that the stock of copper has never been so large as at present.

The price of copper has dropped so low, that only mines putting out exceptionally rich ores can pay small dividends, and the great majority of them find it difficult to make both ends meet. They use the method known as the "Gallic Process."

In the Australian colonies no such ores as just mentioned are worked at the present moment, and it is needless to state that the copper industry in Australia is far from being in a flourishing condition. Several mines have stopped work. Others have reduced their output, and unless the price of copper rises or they find a cheaper way of producing, all the copper mining companies of Australia will have to close their works.

This cheaper way of producing copper from the ore was discovered three years ago by a French metallurgist, Mons. Pierre Manhès, of Lyons, and after repeated trials, he succeeded in perfecting his system, and the Manhès process is now used by the leading copper smelters throughout the world.

Owing to the price of fuel and labour, the French copper fields remained unproductive for a long time. As in all similar cases, necessity was the mother of invention. For long years Mr. Manhès studied to discover an economic method which would allow to work the French mines, and French ores are now converted into copper at Eguilles, three miles from Limoges, where at the present moment fifteen tons of copper are produced daily, and the plant to double this production is now in course of erection.

Before describing the new process, and in order to thoroughly appreciate the advantages of it, we will briefly summarize the several operations of the gallic method still used in Australia. We will thus be able to compare and judge. The gallic method comprises at least six operations, and sometimes more.

It is only when native copper or very rich carbonates are to be treated that the number of these operations can be reduced.

Reverberatory furnaces of two kinds are exclusively used to-day :— Roasting and smelting furnaces. The fuel used is coal or wood. The process varies somewhat at different mines, but the main features are the same.

As we are all acquainted with these furnaces, a description of them would be superfluous. We shall consequently limit ourselves to enumerate the six operations of the gallic process :—

1.—The first operation lasts from 12 to 24 hours ; it is the calcination or roasting of the ore. (After this operation the colour of the ore is brownish black.)

2.—After the roasting the ore is smelted with the slag obtained in the operation No. 4 in a furnace called ore furnace, and the product is called *coarse metal*, and contains about fifty-five per cent. of copper. It takes about five hours to smelt the charge of the furnace, which is then stirred and skimmed and the metal drawn off.

3.—The coarse metal of No. 2 is then roasted in an open-air roasting furnace; the matte is frequently stirred, the operation is generally finished in 24 hours, and towards the last the temperature is raised.

4.—The coarse metal or granulated bronze matte of No. 3 is smelted, with the addition of fluxes rich in oxydes of copper, such as the roasting and refining slag resulting from both operations No. 5. and No. 6, and carbonate of copper or ore containing oxyde of copper. This produces the rough metal, containing 75 per cent. of copper and the metal slag smelted in No. 2 operation. The matte must be white metal.

5.—This operation is called roasting. The white metal ingots of No. 4 are introduced into a smelting furnace like No. 2, with a slight difference for the introduction of the air. The product is composed of roasted slag with blister copper, which contains about 95 per cent. of copper. The temperature is regulated so that the ingots are smelted drop by drop, within 6 to 8 hours. This blister copper is again cast into moulds.

6.—The last operation is the refining, which produces the marketable copper, and takes about 15 hours.

By this short enumeration it is easy to see how tedious and expensive this gallic method is; and it is this method, slightly modified, which is still applied in all the Australian mines.

Let us now examine the Manhès process. The object of this invention is to obtain in one operation in the Bessemer Converter, or in any other revolving or stationary converting furnace, copper at 98 to 99 per cent., by means of forcing air, under sufficient pressure, through the molten ore.

The raw copper thus obtained in one operation needs only to be refined by the ordinary means.

The ore, without any previous calcination, is smelted in any kind of furnace. This smelting is for the purpose of slagging away the earthy matter by concentrating the metallic parts into a matte or regulus, more or less rich in copper, but always containing iron and sulphur. The liquid matte is tapped from the ore-smelting furnace direct into a converter, which has been previously heated to a sufficient temperature. Under the action of the blast the sulphur is eliminated in the state of sulphurous acid, as also the other volatile substances, such

as arsenic, antimony, etc., and at the same time the iron is rapidly oxydised and transformed into silica by contact with the earthy matters which form the lining of the converter, and if necessary by the addition of silicious flux ; the slag is removed by the ordinary process, and the copper remains alone in the apparatus.

The operation takes very little time, and when finished the raw copper is cast either into ingots, or preferably poured into a refining reverberatory furnace direct. This furnace is previously heated, which avoids the necessity of re-smelting the metal to refine it.

The slag from the converter contains still some copper, in the shape of oxydes and granulations. These are assorted, and those which are considered too rich to be rejected are passed into the next operation. But the best way is to smelt them in a cupola furnace, with suitable flux, in order to obtain black copper or matte, and slag which is sufficiently poor to be rejected. However, as this slag is always very rich in oxyde of iron, it can be used with advantage as flux in smelting ores or other quartzy matters.

When the matte contains much iron, which attacks the ordinary earthy lining of the converter, it is necessary to make this lining of a basic material, such as lime, magnesia, etc., and to add a silicious flux, which will slag the oxydes produced.

In all the applications just described Mr. Manhès has mentioned in preference the use of the Bessemer converter, which is best adapted to effects of intermoleculary combustion, which is the basis of his process. However, for the complete success of the operation it is necessary to dispose the converter in a special manner, which we will now describe.

While the copper is being produced, this metal, owing to its density, falls to the bottom of the apparatus ; now, if, like in the converter used in the iron metallurgy, the blast enters the bottom of the apparatus by vertical blast-holes, it is compelled towards the finish of the operation to traverse metallic copper, which, containing no more combustible elements is solidified by the contact of the cold blast which soon brings on the obstruction of the blast holes. This could be avoided by forcing air, previously heated, but this is not practical and very expensive, while a very simple arrangement of the converter gives the same result.

This arrangement, which, however, may vary in the details, merely consists in leaving, below the level of the blast-holes, a sufficient space for the metallic copper to gather as soon as produced, and where it is then sheltered from the contact of the blast ; the capacity of this space must always equal, if not be superior, to the one that must be occupied by the metal produced during the operation.

Generally to obtain this result, Mr. Manhès replaces the vertical blast-holes, which open at the bottom in the common Bessemer apparatus, by horizontal blast-holes placed all around the converter and opening into it at the desired level above the bottom of the apparatus.

But Mr. Manhès obtains better results by the use of his last invented converter, of which you see a model before you. This converter has blast-holes on one side only, and is then more or less inclined, so as to blast at any desired level into the molten mass. (Plate I.)

In this manner, till the end of the operation, the blast passes through matte still containing combustible elements ; the metal is not chilled and the blast-holes do not get choked.

In conclusion, with the gallic method from eight to fifteen tons of coal or an equivalent quantity of wood is necessary to obtain one ton of copper, by the Manhès process only one and a-half tons of coke or an equivalent quantity of wood is required per ton of copper, including the motive power for the blasting machinery.

With the new process the labour is reduced by half. Consequently by the methods used until now the cost per ton of copper is from £12 to £16, while by the Manhès process it is reduced to from £4 to £6, according to the quality of the ore, the price of fuel, and the price of labour.

By the old method a considerable number of reverberatory furnaces are required and from 10 to 15 days are necessary to transform the ore into copper, whilst by the Manhès process the same transformation is made in four hours.

You see that the process is simplicity itself, and it is a wonder that it was not discovered before. It recalls an anecdote on Christopher Columbus : When told that anybody could have discovered America, he simply asked the gentlemen present to make an egg stand on its end ; they all failed. He, taking the egg, slightly cracked it on the table and there it stood. It was surely simple enough.

All attempts at blasting copper ore failed until Mr. Manhès conceived the idea to constantly blast through the matte above the level of the copper produced. It must be added, however, that after the principle was discovered, it still took Mr. Manhès about two years before he succeeded perfectly in one operation. It is therefore not to be wondered that if it took a man of his science and his practical knowledge all that time, his pale imitators in Australia did not meet with any kind of success with their plans.

In presence of the immense advantages of the Manhès process, the question arises why the Australian copper mine proprietors have not yet adopted the process. The author begs leave to briefly state his opinion in this matter :—The process is so simple that attempts have been made, and are being made, at counterfeiting.

There is no doubt that Mr. Vivian, of Swansea, the Parrot Silver and Copper Company, and Mr. Cousins de Lata, in Chili, have bought the patent rights for their respective countries; but it can be easily understood that these people have not the slightest interest in posting others as to the advantages of the process.

We think that the proper way for the Australian copper mine proprietors to convince themselves of the perfect working of the process would be to communicate with the inventor himself, and send a competent man to the Eguille works, where every facility will be afforded him to examine the working in all its practical details.

The adoption of the Manhès process in these colonies is only a question of time, and probably not a long time. It is to be hoped that the copper mine proprietors will be forcibly reminded of the national motto, "Advance Australia," and will adopt this great invention to save their properties.

The paper was accompanied by several diagrams and models from which Plate I. has been prepared.

THE MANUFACTURE OF BREAD BY THE DATHIS PROCESS.

By CLEMENT VAN DE VELDE.

Like other manufacturers in this age of progression and cheapness, the bread baker is compelled to turn his attention to mechanical appliances for the purpose of improving the quality of his product, increasing the yield from the raw material, lessening the waste, and reducing to a minimum the cost of manufacture.

The patent mechanical appliances of Mr. Dathis have been devised to effect such improvements. They have lately been perfected and are now in use in several of the large continental bakehouses with a success so marked, that they bid fair shortly to revolutionize the trade.

Mr. Dathis' invention necessarily deals with the two operations of kneading and baking, towards the perfecting of which he has devoted much attention.

KNEADING.

Kneading is, without a doubt, the most important operation in the manufacture of bread. The mechanical means hitherto adopted to take the place of hand labour at this work having not resulted satisfactorily, the latter is still generally resorted to.

Hand kneading entails a certain amount of dexterity and a very considerable display of muscular energy. In large cities the workmen are no doubt skilled, and are highly paid, but it is quite otherwise in country places and in factories at distances from important centres, where they are obliged of fabricating the bread necessary to the daily alimentation. As regards cleanliness and regularity of manipulation, hand kneading offers many inconveniences. Besides, there is always some danger that the germs of contagious diseases may be communicated to the dough, and frequently the temperature of the oven is not

sufficiently high to destroy their activity. Considerations like these are of material importance from a hygienic point of view and wherever possible, mechanical kneading is much to be preferred.

Dough, prepared for bread, should be soft, light and smooth, a state only attainable by a thorough mixing and peculiar style of kneading, the expanding or drawing out of the dough without any fulling action —a sort of teasing—so as to ærate it in a thorough manner.

Hand kneaded dough rarely presents these qualities, and the best proof to be given is that the bread from it often mildews, a sure sign that the treatment has been insufficient or imperfect.

Such also is the grave fault of the mechanical kneaders hitherto designed, these are mixers pure and simple, and though they stretch and draw out the dough, there is always a subsequent compressive action. As a consequence, the dough is not raised enough, the ærification is imperfect, and the bread produced from it is oftentimes heavy and sad. The arrangements of the apparatus, too, are bad, difficult, not to say impossible to clean, and fermentation hurtful to the quality of the bread is produced.

It is these great drawbacks Mr. Dathis has surmounted by his ingenious contrivance, which, subjecting the dough to a continuous expansion or drawing, and exposing each part of it to the action of the air without any after compression or fulling, fulfils the desired conditions for the preparation of wholesome bread.

The Dathis' kneader (Plate II.) is composed of a trough A, seated secure in a second basin B, revolving upon an axis, so as to present every part of the dough contained in A to the action of the kneading instrument b, having the shape shown upon the accompanying plan. These lift the dough constantly by capillarity, to mix it and knead it by stretching, ærating and blowing without ever compressing, an operation which gives to the dough an incomparable suppleness and lightness.

The trough with its motion and the shaft bearing the motive pulleys, fly wheels, and the crank to work the kneading fingers, are all fixed upon a cast-iron frame work.

The kneading fingers b are fixed to the extremity of levers c by means of regulating screws d. These levers are worked by cranks e, fitted to shaft F, put in motion either by belting or crank. The extremity f of these levers is joined to the hinged shank h which serves as a resting point to part f oscillating around the extremity g of the rod h. This point f can, by means of the groove k with which the lever is articulated at this spot, and of the pression screw l, be raised or lowered so as to regulate the depth of the motion of the fingers b in the trough A. Owing to this disposition, the ends of the fingers describe at each revolution of shaft F—a closed curve of elliptical form.

The trough A, intended to contain the dough, rests upon the basin B of greater concavity. This basin bears at its lower part, a toothed crown m, worked by a spur wheel n, placed at the end of the horizontal rod t. This rod t carries another spur wheel p, geared with a spur q, placed at the lower extremity of an oblique shaft, receiving its motion at the upper part by means of a spur wheel geared with the screw v placed upon the shaft bearing the crank.

The leaven used in the preparation of the dough is kept in an apparatus consisting of a small vessel of wood a (Fig. 1 plate II.I) or any other material with a lid b having an air-tight joint c (this lid may be of glass, so that the growth of the leaven may be watched) ; in the centre is arranged a bung-hole d, screwed upon this lid b ; the empty space in the middle of the bung is filled with cotton which filters the air admitted into the apparatus and prevents the fermenting molecules to enter and decompose the leaven.

The process of working the trough is as follows : —

1st.—A certain quantity of tepid water is put in the lower basin B to keep the dough, which is to be kneaded in the trough at a suitable temperature.

2nd.—In the trough A are put the leaven, the flour, the liquid, and the accessories, in varying quantities.

3rd.—The fly-wheel is turned from left to right ; at first very slowly to allow the flour to absorb the liquid, then a little faster until a speed of 70 revolutions per minute is attained.

4th.—At the end of 10 minutes, the dough is left at rest for two to three minutes, thereafter kneaded for a further 10 minutes ; it is then ready.

5th.—Put the dough to rise in a convenient vessel.

6th.—After each operation be careful to thoroughly wash the trough with plenty of warm water.

Dough for bread-making can be prepared by three different processes :

1st.—With *leaven*, i.e. by taking the dough of a previous day's preparation as a ferment.

2nd.—With *leaven and yeast*, combined, i.e., by utilising a portion of fermented dough, to which is added a portion of yeast, so as to obtain a more regular and more rapid fermentation.

3rd.—With *yeast alone*, using only this body as agent of fermentation.

1st Process.—The first process is the oldest ; the product employed is economical, as the ferment costs nothing, but it is the most expensive as regards labour ; it is also less rapid and safe.

The lack or excess of fermentation of the dough at each operation, the variations of temperature, the bad preservation of leavens, and the imperfect rehandling, are all so many causes of failure. Besides, the leavens which are too old, or badly worked, give to the bread a nasty taste.

2nd Process.—This process is safer, especially when young leavens are used. It is the one generally employed for making common bread, named household bread.

3rd Process.—Is the most costly as regards product, but the most rapid and economical as regards labor. It is also more reliable and is used in preference for the manufacture of fancy bread with or without the addition of milk.

Rise of Bread Dough.—The dough should be put to rise after kneading in a recipient fitted with a moveable piston resting upon the dough, with an electric bell ; as soon as the dough has risen to the height wanted, the bell sounds. (Pl. III. fig. 2.)

In this recipient the first, second and last leaven can be put to rise.

The capacity of the troughs is as follows:

There are 3 sizes of the Dathis' trough

1st—Trough with 2 arms.
2nd do 4 arms.
3rd do 6 arms.

Below are given the maxima quantities of dough which can be obtained with the troughs, and the corresponding quantity of flour.

Designation.	Trough with two arms.	Trough with four arms.	Trough with six arms.
Diameter of trough	1 ft. 9⅜ in.	2 ft. 9½ in.	3ft. 11 2-8in.
Quantity of flour employed	40 lbs.	108 lbs.	242 lbs.
Quantity of dough obtained	66 lbs.	176 lbs.	396 lbs.

BAKING.

General Considerations.—Bread is almost exclusively baked in brick ovens, which vary in shape ; in these wood is burned to raise the walls to a suitable temperature, the radiation from which produces the required heat.

Among the numerous inconveniences of this system of ovens, the following may be mentioned :

1st.—Owing to the disposal given to these ovens, it is necessary to heat them before baking.

2nd.—It being necessary to develop in the oven a much higher temperature than is required for the baking of the bread, the result is a great waste of fuel.

3rd.—The radiation of the heat is very irregular.

4th.—The loaves being placed directly upon the floor of the oven, the lower part of the bread is generally badly baked, hard, and tastes bad.

5th.—The difficulties of putting the loaves in the oven and taking them out of the same, an operation which has to be done several times, and during which the door of the oven re-

maining wide open, the bread receives the cold air, and its steady development is stopped.

6th.—Putting the loaves in the oven becomes a difficult matter when small loaves have to be baked. Not being able to do this operation with the desired rapidity, it often happens that those put in first are already baked or burned when the last ones are put into the oven ; hence a great loss in the manufacture.

7th.—Taking out the wood after heating the oven causes a considerable amount of smoke and disagreeable smell, and the partly consumed wood which is taken out of the oven and laid upon the soil for extinguishing it, may in some cases be the cause of fire. Besides, the heat left after taking out the bread is utilized to dry the wood for the next baking. This dried wood may also be a danger of fire.

The use of the Dathis' oven, of which a complete description is herewith, does away entirely with the inconveniences we have just mentioned. With it is obtained a concentrated heat, radiating upon the whole periphery of the objects submitted to its action. This oven is fitted with a separate and distinct fireplace, which allows of the use of any combustible as coal, coke, wood, &c., by which the oven is kept constantly hot. One hectolitre (about 22 gallons) of good coke is sufficient for heating an oven of 6' $6\frac{1}{2}$" during 12 hours.

The loaves can be put in and taken out of the oven at once ; this avoids the loss of heat, and consequently produces a great economy of combustible. The furnace can be easily cleaned or repaired by removing the cylindrical part of the oven, which only rests upon the lower part that comprises the furnace.

The Dathis' oven is composed of three parts :—(Plate IV.)

1st.—The lower part forms a pedestal and comprises the furnace and the chimney.

2nd.—The oven proper.

3rd.—The lid with its fittings for lifting in, &c.

The lower part is supported on short iron legs for the ovens of 1' 8" and 3' 3" diameter, and by four cast iron columns for the ovens of

6' 6" diameter, and is formed of a circular bottom of fire-proof plates b b, resting upon a sheet-iron plate c ; this bottom has a cylindrical double border composed of fire proof plates d and ceramic plates f, held together by an iron corner plate. The furnace F is in front of the centre of this circular bottom and below it. It is composed of a flame bridge j, of flues k, and of an ordinary horizontal grate with ash box. The chimney occupies the position z shown upon the plan.

The oven rests upon this lower part, and is composed of a sheet-iron cylinder g, closed at the bottom by a convex sheet iron h, with a double plate i, forming a metallic lense. This sheet iron receives in a direct manner the heat of the furnace, the flame-bridge of which is applied against the double partition i, so as to compel the flame to form a double crown of fire, embracing the whole surface of the sheet iron h ; the hot gases escape through the chimney, filling the conduct k. The caloric rays are then stored in the cylinder, according to the curve of the bottom h.

Above the sheet-iron h, is disposed another hollow diaphragm l, open at the middle l', and intended to distribute the heat in the whole extent of the oven.

A cup or a cock m, fitted to a pipe m', allows the introduction of water into the sheet-iron basin l'', placed upon the sheet h, concentrically to the opening l'.

The introduction of this water, which can be made at any desired moment, and particularly at the time the bread is put into the oven, produces a hot mist, which spreads upon the object which is cold at the beginning, and aims at glazing the loaves and facilitating their development.

Over this diaphragm l, is the superior plate A, formed by the concave sheet y, and of a flat sheet X, containing between them a layer of air for the purposes of :

1st —Equalizing the heat over the whole surface of the partition X.

2nd.—To oppose to the passage of the heat a more or less amount of resistance, according to the amount of vacuum between the partitions y and X.

3rd.—To establish in this manner a sure equilibrium between the direct heat and the reverberatory heat.

Above the flat partition X is placed the tray intended to receive the loaves. This tray rests upon rollers fixed to the sheet-iron X, which allows of its being turned so as to select the loaves wanted first.

The use of this tray gives the following advantages—

1st.—Putting the whole batch in the oven at once.

2nd.—Taking out in like manner.

3rd.—The mist can reach the bottom of the loaves, hence facility in their development.

4th.—Suppression of the sprinkling of the bottom of the loaves with flour or sawdust, so as to prevent their sticking to the shovel used for the putting them into the oven, as under the old system.

5th.—Isolation of the loaves from the floor of the oven, and consequently suppression of the dirt the oven contains generally after having been cleaned in an imperfect manner.

The cover P in sheet-iron, has the form of a flattened ellipsoidal cap, and is fitted upon the whole of its outside surface with an isolating envelope ; the effect of this is to reflect the heat upon the outside surface of the loaves. This cover can be raised or lowered by means of a lever B, with equilibrating weight B', supported by a column D. This cover is fitted with handles q, q, with glass peepholes r, r, to watch the inside of the oven, and with a thermometer t.

When convenient, an electric lamp can be disposed upon this cover, to light up the inside of the oven, so that the progress of baking may be observed.

The cover of the ovens of 1' 8" and 2' 5"$\frac{1}{2}$ diam. is taken off by hand, and also the tray that receives the loaves.

For the ovens of 3' 3" and 6' 6"$\frac{1}{2}$, the covers are taken off by means of the system above described. The loaves are placed in position by hand only for the ovens of 3' 3".

As regards the ovens of 6' 6" diameter, the taking out of the tray bearing the loaves can be done by means of a special apparatus, fixed with hinges, n, n, on to the column D, and having claws worked by hand lever.

The latter ovens are fitted with turning tables placed before, and mounted upon a spindle or upon a truck destined for the service of the ovens.

Upon those tables the trays are placed to arrange the loaves as required before baking.

The working of the oven is as follows :—

1st.—The loaves prepared to be baked are placed upon the trays which are introduced into the ovens when the desired temperature is obtained.

2nd.—Follow the indications of the table given below concerning the temperature.

3rd.—Put 3 oz. of water in the injector as soon as the apparatus is closed, and $1\frac{1}{2}$ oz. of water three or four minutes afterwards, for the ovens of 3ft. 3in. diameter. For the other ovens, the quantity of water to be employed is in proportion to the surface of the tray.

TABLE OF TEMPERATURES TO BE FOLLOWED :—

	Temperature of the oven in Fahrenheit degrees.			Time for baking (min.)
	When putting in.	Half baking.	When taking out.	
Large loaves unsplitted of 4 lbs.	414	396	396	50 min.
Large loaves splitted of 4 lbs.	414	396	396	50 ,,
Loaves unsplitted of 2 lbs.	432	414	414	40 ,,
Splitted loaves of 2 lbs	432	414	414	40 ,,
Fancy bread	450	432	432	25 ,,
Rolls	468	432	432	20 ,,
Cakes made with thin dough and put into a mould	432	396	396	45 ,,

There are 4 sizes of ovens of the Dathis' system, namely, of 6 ft. $6\frac{1}{2}$in. ; 3ft. 3in. ; 2ft. $5\frac{1}{2}$in. ; and 1ft. 8in. diameter.

The following table shows the quantity of bread these ovens can turn out in one baking :

	Ovens of			
	6 ft. 6½ in.	3 ft. 3 in.	2 ft. 5½ in.	1 ft. 8 in.
Splitted loaves of 4 lbs. ...	15	4	2	...
Unsplitted loaves of 4 lbs ...	17	5	2	...
Splitted loaves of 2 lbs. ...	20	5	2	...
Unsplitted loaves of 2 lbs. ...	22	6	3	...
Rolls, each one made with 2oz. of dough	200	46	24	12

The paper was accompanied by several diagrams, from which Plates II. to V. have been prepared.

The President informed the members that Prof. Warren had resigned his seat on the Council, on account of pressure of business, and that Mr. G. A. Key had been elected a member of the Council in accordance with By-law 3, Section IV.

MINUTES OF PROCEEDINGS,

14th JANUARY, 1886.

Walter Shellshear, President, in the chair.

The following candidates were balloted for and duly elected as

Members :

PERCY ALLEN.

H. P. FROST.

Mr. Albert Leahy then read the following paper, and explained that it was a compilation, and also a translation from the French of papers by Mons. M. J. Banneux, Engineer-in-Chief of Telegraphs, Belgium, and Mons. Mourlon :

The VAN RYSSELBERGHE SYSTEM OF SIMULTANEOUS TELEGRAPHY AND TELEPHONY,

By ALBERT LEAHY, C.E.

Since the first installation of the telephone in the commercial centres of the world, it has been seen how admirably the invention of Graham Bell has lent increased facilities to the transactions of commerce and of industry, and it has only remained, in order to enable us to derive the greatest possible benefit from that invention, to extend its use to long distance communications, not merely from house to house, but from town to town, and from country to country. Some idea has naturally been entertained of utilising the telegraph poles, already in existence, by placing upon them for purposes of telephonic experiment a wire or wires parallel to those of the telegraph. Directly, however, that is done we find an apparently insurmountable obstacle in the way of success in the shape of "induction," which has the effect of producing in the telephone a frizzling sound, which, for want of a better name, has been called "telephonic frying." These discords, which drown articulation and render all communication impossible, proceed from the telegraphic currents conveyed by the wires adjoining or in the vicinity of those employed for telephony. It is in effect a reciprocal influence

exercised by one conductor upon another, which is parallel to it, and it is goverened by the variation of the electric current in the disturbing circuit. Such was the great obstacle opposed in the first instance to long distance telephony.

If these repercussive noises were of such intensity in the circuit of a wire which was merely in the vicinity of a telegraphic conductor, what would have been the result if a telephone had been placed actually in the circuit of the telegraphic wire? Could one have dreamed of suppressing the tumult, the deafening uproar which would then have arisen? Nevertheless that is the problem which M. Van Rysselberghe has had the audacity to attempt and to solve. We say audacity, because the difficulties of the problem were not only great, but they were numerous.

Having once mastered the "induction" it was necessary to maintain the secrecy of the telegraph by rendering its signals inaudible in the telephone; it was necessary to prevent the possibility of the telephone intercepting even the smallest portion of any telegram passing by the wire to which it was connected, and it was required to find the means by which the telephonist having the telegraph circuit in his charge should be unable to prejudice that circuit, as by interfering in any way with its conduction or insulation or by putting it to earth. That others have had presented to them the same ideas, and that they have engaged in the discussion of the same problem, before or after M. Van Rysselberghe, it is quite possible. The fact, however, is uncontestable, that to him alone the honour of its practical solution is due.

The Van Rysselberghe system is based almost solely upon the remarkable fact discovered by him, that "when the suddenness of the emissions and extinctions of the currents is eliminated those currents become inaudible in the telephone." For the sudden changes of electricity now in use for telegraphic purposes he substitutes gradual currents; that is to say, currents which gradually increase at the commencement and as gradually decrease in strength at the end of each signal. This graduation, which occupies but an infinitesimal portion of time, is obtained by the interculation in the circuit of small graduating electro-magnets, or again by placing upon the line certain condensers, which act as derivators, or, finally, by a combination of electro-magnets and condensers absorbing a certain quantity of the current, which they restore on the circuit being broken. Under the influence of the

currents graduated in this manner the diaphragm of the telephone is yet subject to movement, but it no longer vibrates. The telegraphic current, therefore, produces no sound in the telephone. In other words the telegraphic currents are completely silenced or rendered inaudible, whether they be direct, induced, or derived. By means of this system not only can an effective telephonic service be organised from town to town by utilising the ordinary telegraph poles to carry the telephone wires, but the telegraph wires can themselves be employed for the purpose. The system is one of *anti-induction*, and completely assures the independence of the two services. It establishes between the telegraph and the telephone circuits a separation of such a kind that, whilst the rapid undulations of the low tension currents of the telephone are readily transmitted, an impassible barrier is opposed to the telegraphic currents, which, it is scarcely necessary to observe are of an essentially different nature. The greatest beauty of the system is its simplicity. We will now endeavour to explain with the assistance of these diagrams some of the tests and ideas applied by M. Van Rysselberghe with the idea of suppressing in a telephonic compass the effects of conduction caused by the telegraphic working of the conducting wires that adjoin and run parallel, as well as the utilization of these same wires for the duplex correspondence—telegraphic and telephonic.

Graduation of the Telegraphic Currents.

As we have already remarked under what circumstances M. Van Rysselberghe was induced to fight telegraphic induction in the primary circuit, which is different to the other processes in general use, which tend to neutralize the effects produced in the secondary or telephonic circuit.

The most marked, and consequently, the prejudicial currents are those which correspond to closing and opening the inducing circuit, and their strength is in direct proportion to the strength of the currents which have caused them at the time of the transmission of a signal. From that time the emission and destruction of the first current should be graduated in such a way that from zero to I it should go on gradually increasing, and from I to zero gradually diminishing. You will then be reducing the strength of the currents induced, and so let them die out gradually, that is in short cause the inside of the receiver to bend only, without however, giving rise to any sound.

After having tried as graduators, manipulators that modified of their own accord the resistance of the first circuit, Van Rysselberghe obtained far better results by making use of electro-magnets and condensors, whose purely electric play is more fitted for the application, and do not call for any modification of the usual telegraphic transmittors.

Take two wires L1 and L2 adjoining and parallel (fig. 1). ; M and R respectively a telegraphic manipulator and receiver ; E a straight electro-magnet of a resistance of about 1000 ohms placed between the battery and the key.

The currents set on the wire L1, by the manipulator M will not be felt or very little so, in telephone T2, and their direct action on telephone T1 is consequently less than if the electro-magnet E were not there.

You would meet with a better result if you had a condenser between the pile or battery P and the line L1 of the transmitting key. (Fig. 2).

In short you will not get any sound from telephones T1 and T2 whatever may be the strength of the pile P when the condenser is connected from the earth between the two electro-magnets E1 and E2, which have then a resisting power of 500 ohms. (Fig. 3).

So that this test may prove an entire success, the telegraphic wire L must be of a certain length, and the resisting power of receiver R must not be less than 500 ohms, and the capacity of the condenser graduator must be roughly speaking of two microfarads for the setting of telegraphic wires.

As regards the Morse system of working, electro-graduators are not necessary when the currents cross (from the start) the reels of the receiver R.

In the case of the Hughes apparatus, a good reduction of the sounds, that are induced, is obtained by simply suppressing the current —putting aside any inclination to graduate. It is then preferable to put an electro-magnet of 1000 ohms in that direction, but the combination which goes best with the varying state of the lines and apparatuses is that of plan 3, namely :—In each terminus office an electro-graduator for the battery, another for the line, and a condenser connected with the earth line.

A very interesting application of the anti-inducing system was made in Belgium after the enquiries made by M. Van Rysselberghe and M. Buels, head of department, on a line 45 kilometres long,

working on the Hughes duplex system between North Brussels and Antwerp (exchange). The working of this line gave cause to a great telephonic noise in the adjoining circuit, which had to be done away with, without interfering with the telegraphic balance. The placing of the wires as follows, (fig. 4), solves that problem. The two sides of the bridge are represented by two electro-magnets, E1, and E2, with movable iron nuts. You regulate the balance in the usual way by means of the rheastat R. Then by sending interrupted currents, you can modify by feeling the length of the inside of the nuts in such way as the equilibrium is maintained under the influence of the powers of statics and dynamics of which the electro-magnets are the seat. The graduator condenser then becomes useless.

We then find from this that

1st.—On a given line one can have a telephonic service by the aid of a simple wire with earth lines, when all the other conducting wires adjoining and parallel traversed by telegraphic currents are provided with Van Rysselberghe's anti-inductor, and

2nd.—That if all the wires are all so provided without distinction, any one of them can allow of a duplex telegraphic telephonic correspondence being carried on, quite regardless of the noises caused by the induction, as experience will show, of those arising from the derivation of currents from one wire to another. In the first place, telegraphic communication is lost, and, in the second, the absolute identity of the telegraphic and telephonic circuits will give effect, in practice, to inconveniences such as to render the combination anything but a desirable one. Having observed this, the inventor has striven to make the two series as independent from one another as possible.

Let TLT1, fig. 5, be a telephonic circuit with an incline, KMN to the earth, C a condenser of $\frac{1}{2}$ microfarad or less : R with a resisting power of 500 ohms or more : T and T1, telephones whose resisting powers can vary from 0·1 to 4000 ohms.

Let the incline KMN be suppressed or maintained, the persons corresponding will not perceive any tangible difference in the strength of the telephonic currents. We have tested this on (overhead) lines of 45 to 110 kilometres. On the line from Brussels to Paris, 320

kilometres long, and on the submarine cable from Dover to Ostend, 138 kilom. long.

As regards the relations of resistance to be established between the line, the telephonic receivers, the second wire of the inducing reel of the microphonic transmitters, the battery, the microphone, and the first wire of the reel, experience has showed, by the admitted laws in telegraphy, telephones having only a few turns of thick wire, work very well on overhead lines of more than 300 kilometres long, and that the results are most favourable when the resistance of the inducing circuit at the transmission place is reduced as much as possible. That is the reason why M. Van Rysselberghe has made use of an electrical generator of batteries, with small inside resisting power, such as accumulators have, and so multiplies the microphonic contact by coupling them at the surface.

Simultaneous Telegraphing and Telephoning.—By applying to a telegraph wire the principle indicated in fig. 5, you set up the duplex system as shown in fig. 6. In which the condenser graduator C1 has a capacity of 0·5, or, if desired, of 0·1, of microfarad only. And condenser separator C2 a capacity of 2 microfarads. The utter independence of the two ways of corresponding is thus realised.

Van Rysselberghe's anti-induction system has been tried on several occasions on the Belgium telegraphic net work with the greatest success. We shall specially mention a case where three operators, placed respectively at the Brussels, Ostend, and Antwerp observatories have conversed without any difficulty by means of a wire of 4 millimetres thickness, placed on the line poles connecting these localities, and that, too, during the busiest time of the Morse and Hughes system, with a number of wires running parallel with the first, some of which, the ones that made the most vibration only, had been set up on this system. They at that particular time made use of microphonic transmittors, and of bell receivers, modified by Van Rysselberghe with a view of reproducing the voice as loud as possible, to overcome those prejudicial noises, which had been intentionally allowed to exist.

We also beg to point out the transmission by telephone regularly from the Legislature Palace, Brussels, to the offices of a daily paper at Gand, of the full account of the parliamentary debates, quotations of change and markets by an overhead wire of the telegraphic line from Brussels to Ostend, which wire serves at the same time for the

transmission of the voltaic currents working the *telemeterograph* placed at the observatories of these two cities.

This last test is an instance of the resources possessed by the system used to obtain a mutual independence of two services, with one same conducting wire. Two stations, A and D, can correspond by telegraph, whilst two other intervening stations, B and C, can carry on a conversation by the wire which connects the two first ones. But better still, you can connect telephonically a telegraph wire of a given length in such a way as to increase without interfering with the number of stations in connection. E1 and E2, fig. 7, are electro-magnets of 1000 ohms, E3 and E4 are reels, or rather electro-magnets of about 500 ohms, R1 and R2 receivers of at least 500 ohms, and C1 — — — C5 condensers of 0·5 microfarads. By these conditions T1 and T2 on the one hand, and T3 and T4 on the other, can communicate by telephone at the same time, as the end stations can exchange telegrams.

Let us admit for argument's sake that all the wires of a given overhead line are provided with the anti-induction system, and also with side connecting wires, those that touch the earth at the central office, and in general all telegraphic conducting wires whose working is likely to cause induction currents or derivation in a telephonic circuit. Is it possible to make use of several single wires of this line for independent and simultaneous verbal communications? We decidedly deny it: all that is said by one wire is distinctly understood by the others. The greatest enemy, therefore, the telephone has, is no longer the telegraph, but the telephone itself.

Henceforth, every time you may want several telephonic circuits between two given points, you must have double telegraphic wires which shall possess independently their usual strength. M. Van Rysselberghe gives the two following solutions to the question:—

First Solution, Fig. 8.

In this plan S1 and S2 represent resisting powers of at least 500 ohms.

R2 is a receiver with resisting power of at least 1000 ohms or more, and E2 is an electro-magnet of about 1000 ohms.

The formula S1 x L2 = S2 x L1 is not disregarded. According to the rules of the telephone there is an advantage in taking for E1, S1 and S2 for electro-magnets in order not to fulfil too rigorously that condition of equilibrium.

Second Solution, Fig. 9.

L1 and L2 are telegraphic wires, E1, E2, E3 and E4 are electro-magnets of 500 ohms. C1 and C2 condensers of 0·5 microfarads ; C3 and C4 condensers of 2 microfarads. R1 and R2 telegraphic receivers with a resisting power of not less than 500 ohms. It is this latter combination which has been so successful in Belgium on the Brussels and Antwerp line, between Haeren and Berchem (35 kilometres) and in Holland between Amsterdam and Haarlem (18 kilometres).

Should you desire to make use of an international telegraphic wire for a telephonic service, or prevent it from interfering with a verbal communication exchanged on wires of the same line, you can forego the appropriation of a conducting wire in a foreign territory, all you have to do is to place at the frontier, or at a suitably convenient given spot, an electro-magnet of 500 ohms, and to place a condenser of two microfarads at the branching off of the line to the ground.

We cannot dwell too long on the necessity of insulating electrically with the greatest care, in all duplex systems, the connecting wires and the instruments of telephonic stations, in order to avoid the mixing of telegraphic signals or the loss of them in the earth line.

Condensers require the greatest care, because they must withstand the working of the potential caused by the most powerful batteries used in the telegraphic system. They are submitted to the following test :— A circuit consisting of a battery of 300 element (Leclanché) of three electro-magnets of 500 ohms, and of a disconnector with quick vibration, at the edge of which are connected a branching off circuit, the appurtenances of a condenser being protected by a conductor. The condenser ought to stand without injury the extra currents thus produced.

Nevertheless in the case of accidental waste, it is essential that you should combine matters in such a way that the replacing of condensers and conductors should be done instantaneously.

We now have to show the way of connecting the metallic circles of the town lines with single line circles of the subscribers to the suburban lines.

This problem was entirely solved in England at the time the post-office decided to establish, on its telegraphic poles, for the use of the subsidized companies, special circles composed of wires wound round one another, after the principle of Professor Hughes (see Journal of the

Society of Telegraph Engineers, Vol. VIII., 1879). We know that the solution consists in the placing of an induction reel, one of whose wires form part of the metallic circle of the trunk line, and the other of the conducting wire connecting the subscriber, and whose two extremities touch the earth.

In spite of the double inductive transformation introduced by increase in the telephonic system, and the increase of the resisting power of the intervening circle, correspondence at great distances is still possible, provided the relation of the resisting powers of the wires of the repeating reels are properly regulated. In the Van Rysselberghe plan, the question gets rather complicated on account of the interference of the telegraphic currents, and of the necessity of making sure of the discharge of the condensers separators (fig. 9) The inventor connects to earth the centre of one of the two circles of the induction reel, which composes the telephonic bridge. You can picture to yourself, as the arrows in fig. 10 show, the direction of the telephonic currents. In fact, you must prevent the mutual reaction of the two parts of the reel, and divide that one. Each half makes a reel of a distinct inducing power, having nothing in common with one another, by the connection with the earth and the axis or nuts of soft iron (fig. 10) are placed perpendicularly between them.

This placing of the axis is also carried out in the putting up of several graduating electro-magnets—when you are compelled to place these accessories side by side—at all events Van Rysselberghe's obtains the desired result in inserting each electro-magnet in a cylinder of soft iron.

A peculiar coincidence of a combination is the following, fig. 10. If in the absence of any telegraphic working, you were to insulate wires L1 and L2, there is very little difference between the intensity of the reception, and that obtained by aid of the double circle.

It is clear that the carrying, or rather the repeating reels, and the condensers separators ought to be in the central telegraphic offices of the trunk line, and not at the central telephonic offices ; it is also desirable that each connection between these offices should be made by a wire coupled on one side through the induction reel, with "return" wires that touches the ground, and that these conducting wires should be insulated in the same way as telegraph wires. Up to the present, whilst depending on the telephonic currents reaching in sufficient

quantity the end of a town line placed on very bad insulators, insulation has hardly been taken into account, reciprocal echoes of neighbouring conducting wires can then arise as much from the branching off as from the induction.

We are of opinion that this should not be neglected if one desires to see correspondence at great distance between subscribers of different towns a success. Perhaps, in certain cases, the strength of telephonic transmittors in general use ought to be increased, pending the invention of a real telephonic "relay." Now, if one central office wants to communicate with another on the Van Rysselberghe system, one ought to avoid the bells worked by voltaic currents and ordinary magnets call, so as not to disturb the telegraphic working of the wires used in the duplex system. Henceforth, telephonic apparatuses ought to produce by themselves a signal sufficiently loud to excite the attention of the office that has been called. We have admitted so far that a telegraphic wire cannot be used for telephonic purposes between two given points, unless it be of a one continuous unbroken length from one end to the other. This is not an absolute condition. Suppose two wires connecting respectively stations A and C to a third B, where they take the earth through telegraphic apparatuses : all you have to do is to shunt these by means of a bridge placed between the line wires in office B, provided each set of apparatuses show a resisting power to telephonic currents of at least 500 ohms.

Supposing you make use—between two given spots—of several telephonic circles, each composed of two telegraphic wires running parallel on the same poles, and used after Van Rysselberghe's system, it is essential that the amount of power (telephonic) which these circles have over one another should be ascertained.

In case conversations held on one of these wires should re-echo to such a degree as to be understood on the neighbouring one, the advantage of having a double wire would disappear, and one would be compelled to limit the duplex correspondence to one single conducting wire, with earth lines. The remedy, in this case, would lie in crossing the wires, as has been done in England, but this new mode of setting up would mean a complete rehandling of the telegraphic lines, and it would not be appreciated in countries where the insulators are fastened on to the poles themselves, and not to arms or cross-trees.

Tests made up to the present day in Belgium on lines of 100 kilometres and less have shown that when each pair of wires are placed parallel and close to one another, the voice thus induced is heard, and words, *i.e.*, portions of sentences are sometimes understood. The induction however diminishes and even disappears when these wires deviate, or better still cross one another in such a way as to run perpendicularly. A very good result is obtained for instance by connecting the first wire on the right of the poles with the second of the left, and the first of the left with the third of the right.

THE VAN RYSSELBERGHE SYSTEM

generally puts a stop to the unequality of the effects of induction of the neighbouring wires on each of the telegraph conducting wires composing the telephonic couple.

To do this you cause to slip on one another the two parts of the repeating reel corresponding with the telephonic wire, which is the most influenced, in such a way as to diminish the induction action of the first and second solenoids. Thus the reciprocal induction of double circuits, placed on the same supports, is hardly felt. It is not of much consequence, in practice, whether a conversation transmitted on a neighbouring wire be heard or not as long as it is not understood.

A direct result of the use of the Van Rysselberghe system, is the strengthening of the telegraphic batteries—to take into account the *extra* fixed resisting power 1500 ohms, brought by the electro-graduators in each circle.

It is only right that a person at the outset should feel alarmed at the expenses they are drawn into, for the setting up must be completed in all the offices whose wires can act on the telephonic wires, either by the induction or branching off of the currents. However if you reckon the expenses caused by telephonic lines, specially put up, for a number of circles equal to that furnished by telegraphic wire, existing in a given network, the advantages, from an economical point of view of the Van Rysselberghe system, are at once recognised. Quite recently the inventor has adopted a new combination, reducing the resisting power to 1000 ohms. Guided by these considerations, and with a view of organising, without delay, the telephonic service between the principal towns of Belgium—the first step towards an international service—M. Oliver, Minister for Public Works, gave his assent to a contract, by virtue of which the firm of Maurlon and Co., of Brussels,

binds itself to provide, under the direction of the inventor, all accessories of the Van Rysselberghe system, necessary for the appropriation of the Belgium network. In conclusion we have to mention an objection raised by Mr. Preece, at a meeting of the British Association, at Southampton, 1882. "What advantage is there in corresponding verbally on a wire to the detriment of telegraghic communication? In England speed is everything, and we eliminate all causes which interfere with speed; consequently there can be no question of electro-magnets and condensers in telegraphic circles: they interfere with telegraphy."

If the automatic Wheatstone were used in Belgium we should have sought to determine *in anima vile*, the influence of the anti-induction plan on the speed of the working of this apparatus, after having taken care to increase the electro-motive force in order to allow the current its primitive strength.

But we do not doubt that the countries which use the rapid system, such as Great Britain, France, Italy, Russia, and Sweden, will consent to make on their lines the tests destined to elucidate pratically that point, and to publish the results for the benefit of the community. Nevertheless they have worked in Belgium, on a line of 244 kilometres, by means of Hughes apparatuses regulated to 150 revolutions without the placing in and the suppression alternately of an electro-magnet of 1000 ohms in the circle producing a false letter or any disarrangement; in fact the most complicated classical combinations were transmitted. Besides, during a period of two months, the North Brussels carried on the service with Paris 320 kilometres at 145 revolutions; the electro-graduator being then inserted in the branching off of the Hughes reel.

This anti-induction system, we believe, can be applied to the Morse system.

The paper was illustrated by a number of diagrams, from which Plate 6 has been prepared.

MINUTES OF PROCEEDINGS,

11th FEBRUARY, 1886.

Walter Shellshear, President, in the Chair.

The following candidate was balloted for and duly elected as

MEMBER:

GEORGE A. HARRIS.

Mr. J. M. Small read part of his paper on "Healthy Dwellings."

11th MARCH, 1886.

Walter Shelshear, President, in the Chair.

The following candidates were balloted for and duly elected as

MEMBERS:

CHARLES E. WATKINS.

GEORGE T. RITSO.

Mr. Norman Selfe then read the following paper, the discussion on which was held at a special general meeting on the 25th March:—

COMPRESSED AIR AND ITS APPLICATIONS,

WITH PARTICULAR REFERENCE

TO

PARDY'S LOW PRESSURE TRAMWAY SYSTEM,

AND A NOTICE OF

THE HYDRO-PNEUMATIC ELEVATOR.

By NORMAN SELFE, M. Inst. C.E., Etc.

INTRODUCTION.

The subject brought under your notice this evening is of undoubted importance to engineers, yet this is the first time it has ever been considered at the meetings of the Association (and the author speaks as a member of it from the foundation). He therefore hopes now to open out a field for discussion and interchange of experiences that will prove mutually pleasant and profitable.

It may be safely said that engineers, as a body, are much better acquainted with hydraulic machinery than they are with pneumatic or compressed air appliances, although the latter are probably more varied in their uses; for while it is true that com-

pressed air can never take the place of water in presses, lifting jacks, and such other machines as are specially dependent on the non-elastic properties of water for their operation, still there are many purposes to which hydraulic power is now applied, and notably the transmission of power to long distances, for which compressed air as well as being like water suitable for transmission through pipes ; possesses the further advantage of being in itself a store of power, and, in other ways to be pointed out, has advantages over water pressure.

The laws that govern the use of water in hydraulic machinery are very simple, there is no compression and expansion, and no storage of power in the water itself ; such storage must be made by a natural head as an elevated tank or reservoir, or be created artificially as in a loaded accumulator. With a knowledge of the laws that govern the friction of water in pipes, and the losses appertaining thereto, you have nearly all the theory you want to enable you to make hydraulic machinery. But, on the other hand, before you undertake the compression of air, and its transmission to a distance, to work an air engine, you are brought to a face with the complex laws of thermodynamics, and two great outlets for loss of power present themselves. These losses are so important that were it not for other and more than compensating advantages which it possesses air, could never rival water as a medium for the transmission of power.

The losses arise thus : First, in the compression of air the whole of the energy exerted to effect its compression is converted into heat, which raises its temperature, and therefore its relative volume, and as a consequence, the relative power to effect the compression is increased, unless this heat is dissipated as fast as it becomes sensible. In a good compressor, as much heat as possible is got rid of during the operation of compressing, the remainder is dissipated through the walls of reservoirs and pipes as the compressed air returns to atmospheric temperature ; so that before the air is employed to work an engine, all the power or heat that was put into it to effect the compression is practically lost.

Secondly. In the expansion of compressed air against the piston of an air engine and the performance of work, the air must part with heat equivalent to the work done (and on this law all cold air refrigerating machines depend for their action), but this loss of heat brings about a diminution of volume in the air expanded in the

cylinder, and a reduction in the work done, so that in the practical compression and expansion of air, an indicator diagram taken from the cylinder does not shew a curve that follows Marriott's law.

The combined losses from the two operations, compressing and expanding air, are not of great importance at very *low pressures* above the atmosphere, but they rapidly increase as the working pressure goes up, until at 10 atmospheres they perhaps amount to 75 per cent. of the whole power. For want of knowledge that is now accessible to all, a great deal of mystery used to surround experiments made with compressed air; and before the mechanical equivalent of heat was understood, much money was wasted in constructing useless machinery, not only in the older countries, but also in this colony. Twenty-five years ago the author made the working drawings of a machine patented here and intended to produce cold by the expansion of air. The whole plant was made by Messrs. P. N. Russell and Co., and tried in Margaret-street close by, and it proved a total failure. He knows *now* that as the air in that machine did no work in expansion, it did not fall in temperature, and no sign of ice from it ever gladdened anxious eyes; but nobody in the colony (in those days, probably) knew where the defect was. At the present time, thanks to the researches of such men as Joule, Carnot, Rankine, and others, the laws of thermo-dynamics are established on a basis that is confirmed by every day practice; and such futile schemes and costly experiments as were made in this colony under the patents of Messrs Sloper, Mort, and Nicolle for producing cold by the compression and expansion of air, are not likely to be repeated.

It is not purposed to import deep theoretical matter and mathematical formulæ from the text books, into this paper. Having, however, paid considerable attention to the use of compressed air for years past, and in order to present the results of theory at a glance, the author lately compiled, from the best authorities available, the two tables marked A and B which indicate, in most instances the sources of his information. The transpositions into English weights and measures, and to Fahrenheits temperatures have been made, as the originals were in French measures. With these few remarks it is proposed to divide the subject into three portions, dealing respectively with: The past and present use of compressed air; The principles involved in dealing with it; and Some recent improvements in its application.

Past and Present Use of Compressed Air.

Up till about the year 1839, say 47 years ago, the principal application of compressed air was in connection with diving bells. The earliest reliable record of their use is given by Taisner, who records that in the year 1538 two Greeks descended in one at Toledo, in the presence of the Emperor Charles V., although there is some reference in the problems of Aristotle to show that the principle was understood four centuries B.C. About 1620 Dr. Halley, in England, improved the appliances used, and sent down supplies of fresh air to his diving bell by means of specially constructed casks; But the first introduction of a compressor or pump to send down a continuous supply of air to the diving bell, we owe to Smeaton in the improved appliances, invented by him for the works at Ramsgate Harbour, in Kent, about 1788. Smeaton's work at Ramsgate, and the diving bell itself are still much as he left them. Diving dresses or Scaphandres, as the French call them, owe their origin principally to John Lethbridge, 1721, Klingert, at Breslau, 1797, Siebe, of London, 1829 (still the best known maker), and later to Cabirol, 1857, and Rouquarol and Denayrouse, 1867. Submarine boats have been designed since 1776 by scores of inventors, but the author is not aware of one yet being constructed that he would care to go down in; they would all, however, have to depend on compressed air for their existence, and are thus just mentioned. Coming now to 1839 again, in that year, M. Triger, a French engineer, proposed the use of compressed air for sinking the cylinders or piles of bridge piers. He did not, however, carry out his ideas, and it was left for two English engineers, William Cubitt, at Rochester Bridge, in 1851, and Brunel, at Saltash, in 1854, to have the credit of the first application of Triger's proposals. As most of you are aware, numbers of bridges in this colony have had their cylinders sunk by this means.

One of the latest applications of Triger's proposals, and in some respects the most notable, is the sinking of the great cylinders 70 feet in diameter for the Forth Bridge, in Scotland. The author had the pleasure a few months since, of descending by the air locks to the bed of the Forth, about 50 feet under water mark, in one of these caissons, where the excavation was going on in a chamber 70 feet in diameter, thoroughly lit up by the incandescant electric light. He also saw

here a novel application of power, being a hydraulic spade, which operated inside the air chamber. The sinking of these cylinders is very ably described in a paper recently read before a Society in Scotland.

In 1840, M. M. Andraud and Du Tessay, appear to have experimented with compressed air to drive a carriage on a small circular railway in France, and in 1845, M. Triger, conveyed compressed air 230 metres from the compressor to do work. In 1849 compressed air was used at Govan, near Glasgow; the compressor being designed by the late Mr. Randolph, and it was of the type that used water on the pistons. The first grand application of compressed air on the continent of Europe was due to Professor Colladon, of Geneva, who, in 1852 proposed to use it for the piercing of the great Alpine tunnel through Mont Cenis. An English engineer, Mr. Bartlett, of the firm of Brassey and Co., has the credit of designing, in 1855, the first pneumatic rock drill. M. Sommeiller, a Piedmontese engineer, who was connected with the tunnel works, brought out an improved perforating machine in 1860, that was used in driving the tunnel, and in 1861 he brought out a design for new compressors with water pistons that were succesfully adopted, and are now known as Sommeiller Compressors. This type of compressor has been used both in Victoria and this colony, introduced by Mr. Ford, of Melbourne.

The success attained in Mont Cenis led to the application of compressed air to the Perseburg mines, in Sweden, and the Vielle Montagne mines, in Rhenish Prussia, in 1863. Next year, in 1864, M. Cornet, after a voyage to England, set up a plant in Belgium, to carry the air 1000 metres from the compressor; and the use of compressed air then began rapidly to extend, up to the piercing of the Great St. Gothard Tunnel, undertaken in 1872. This tunnel is 14,920 metres in length, and without compressed air its construction would have been hardly possible. Professor Colladon here first introduced the injection of water to the compressing cylinders, so as to take up the heat of compression, and that type of compressor is still called after him. From the experience thus gained, up to say—1872-74—by Messrs Colladon and Sommeiller, and the increased knowledge of thermo-dynamics, as connected with the subject, that was available, a foundation was laid for hundreds of successful applications of compressed air that have since been made.

One of the principal applications of compressed air to which your attention should be drawn is its special suitability for the propul-

sion of vehicles on trams or railroads; and a great many people in Sydney have lately expressed their doubts as to whether it could be so applied. I have already mentioned the attempts of Messrs. Andraud and Tessie du Motay, in 1840, and M. Triger, in 1845. Clegg's atmospheric railway was actually in use in London about 1839, but the principle there adopted, under which a piston attached to the carriage worked through a continuous cylinder between the rails, has been long abandoned. Something of the same sort, however, is the pneumatic dispatch system, as used at the Post Office, London; there the carriages are actually blown through the tubes by air pressure, positive or negative, and this system has lately received a great development.

In 1858, M. Sommeiller constructed a small air locomotive. In 1874, the contractor for the St. Gothard Tunnel, M. Favre, employed ordinary locomotives with enormous air reservoirs to draw out the excavated materials, and in 1875, M. Ribourt, an engineer connected with the St. Gothard works, patented a compressed air locomotive, which worked satisfactorily at a pressure of fourteen atmospheres.

At the present time numbers of mines in England and on the continent of Europe employ compressed air locomotives (like the photograph exhibited) as a regular part of their plant. It is to be hoped we shall soon hear of them being in use in N.S. Wales.

The principal inventors who have, up to the present, applied compressed air with success to the propulsion of street cars, are M. Megarski in France, Colonel Beaumont and Scott Moncreiff in England, Messrs. Hardie and James and Mr. Bushnell in America, and latterly Mr. Pardy also in America.

The compressed air tramway of Colonel Beaumont, has been for some years before the public; it was tried on a branch of the North London Metropolitan Tramway in 1881. The author saw it (as improved) at Bootle, near Liverpool, last year. Under this system the air is stored at the great pressure of 1000 lbs. to the square inch; but by means of compound engines most ingeniously constructed, and the application of a supplementary fire and steam jacket to warm the air, it is sought by the advantages of expansion, to make up for the enormous loss in compression. It is said that to draw 56 passengers a single journey of eight miles on a practically level road, the locomotive weighs 8 tons, this great weight being principally due

to the size and strength of the air receivers. The whole machine is complicated, and looks to have very delicate mechanism for rough work.

The Megarski system has had a much greater measure of success than any other air tramway yet adopted. It has had a continuous trial of five years at Nantes, in France, and was tested on the Wantage Tramway in England; it is now being adopted by the North London Tramway Company. M. Megarski only uses 30 atmospheres, or 450 lbs. per square inch, and he heats the air by passing it through hot water, in a special vessel on the driver's footplate, and like Colonel Beaumont, he gets expansive working without freezing up all the exhaust passages of his cylinders. The engine and receivers are all carried on the car itself instead of on a separate locomotive. One of the cars built for the Caledonian Road Tramway, London, was exhibited at work, in the South Promenade, and, in fact, obtained the gold medal at the late Inventions Exhibition, held at South Kensington. The author took several opportunities of riding in the car, and also made an arrangement by which he had a thorough look into the details when the car was stopped for re-charging.

Mr. Scott Moncreiff has made a tramway car with the reservoirs and engines all under the floor as in the Megarski system, his six reservoirs held air at 350 lbs. per square inch. It was first tried in 1875, on the Vale of Clyde Tramway, and subsequently in 1877 it resumed regular duty. The weight of car was $6\frac{3}{4}$ tons empty, and it carried 40 passengers three miles on one charge of air.

A trial has been made on the New York elevated railways, of the Hardie air locomotive, by Messrs. Hardie and James, and with very fair results, the pressure being about the same as that used by Megarski, viz., 450 lbs.; but at Newhaven, Connecticut, a Mr. Bushnell has invented a system, and has worked his engine at the enormous pressure of 3500 lbs. per square inch, which is something like that used in Torpedo practice. Mr. Zahner, the author of a work on compressed air, states that he rode over a mile on a Bushnell engine, during which journey the pressure guage only descended from 1800 to 1500 lbs. per square inch.

In all these tramways systems, the principal object of the designers has been to carry as much stored up power as possible, so as to be able to go the greatest distance without requiring to recharge the reservoirs; and this is done at the sacrifice of efficiency, for

although it is now known how much more economy is the result of using low pressures, yet owing to its greater volume some of these engines could not carry low pressure air to go the distance they now do without taking up the whole of the passenger space with reservoirs. Again, in these tramway systems the charging is done at special stations, and is a tedious process, as the power to be stowed away is proportionate to the load and distance run. In the cases seen by the author it took about twenty minutes, and was effected by coupling on copper pipes. It is hardly necessary to say that the weight of the receivers is almost directly as the pressure carried, that is to say a cylindrical receiver to carry 500 lbs. would be nearly five times as strong and heavy as one of the same dimensions to carry 100 lbs.; it would then propel the same gross load five times as far as the 100 lbs. cylinder. But as the weight of the stronger cylinder would be five times as much as the weaker one, the net carrying power for passengers would be correspondingly reduced. In fact the limit of distance is soon reached in the resisting power of the metal of the receiver, which determines the maximum distance a given receiver will carry power to propel itself. Beaumont's engine of eight tons is said to draw 56 passengers eight miles on one charge; no doubt this would be on good level roads. The Megarski car seen, carried 40 passengers, and weighed nearly seven tons empty, and the company claim that it will run ten miles under favourable conditions.

With all the drawbacks, however, of having so large a proportion of non-payable load, the great loss from using high pressures, and the complication of having to carry a heating apparatus, the Megarski system at any rate is a practical success, and having been on trial since 1879 it would not now obtain an extended application in London if it were otherwise. We will now consider the second part of the subject—

Some of the Principles involved in the use of Compressed Air.

From experiments made years ago by M. M. Regnault, Rudberg and others, on the expansion and pressure of gases between the temperatures of 32 deg. and 212 deg. Fah., certain laws have been deduced, and it is ascertained that the absolute zero of temperature is -461 deg., that is 461 deg. below the zero of Fahrenheit. The four principal laws to interest us now are these: *First*, (what is generally known as Marriott's Law), The pressure of air varies

inversely as the volume with a constant temperature. *Secondly*, The pressure is directly as the *absolute temperature* with a constant volume. *Thirdly*, The volume is directly as the *absolute temperature* with a constant pressure; and *Fourthly*, The product of the pressure and volume is proportional to the absolute temperature. That is to say, if we double the temperature of a given volume of air, and the pressure remains the same, we double the volume; but if the volume remains the same we double the pressure. Thus, one pound of air at atmospheric pressure and at 70 deg. Fah. = 13·342 cubic feet. If we double the temperature, that is double (70 deg. + 461 deg.) = 531 deg. absolute, it becomes 1062 deg. absolute, and this with 461 deg. deducted again, makes it = 601 Fahrenheit. At this temperature, or say 600 deg., one pound of air = 26·659 cubic feet, or double the bulk it occupied at 70 deg., and is nearly at the melting point of lead, 617 deg.

When the temperature is uniform, the product of the volume and pressure is uniform, that is, if the pressure is doubled the volume is halved, and so on; and the curve or diagram follows Marriott's law, and is called an *isothermal curve*. When, however, a certain quantity of air is compressed by a piston in a cylinder so that no heat is given out, the work of compression as internal work is converted into heat, which raises the temperature of the air and thereby the pressure or volume, and the curve of the resulting diagram is called an *adiabatic curve*. The diagram, Figure 4, is from a Sommeiller compressor with a hydraulic piston, by M. M. I. Francois, a Belgian engineer. The line A B C D shews the actual work done, the line B E is the Marriott or isothermal line that would be shewn if no increase of heat took place, and the intervening space represents the power actually lost in the compresser. The line B F is the adiabatic line that would have been followed if some of the heat had not been conducted away by the water. You will notice this diagram only extends to five atmospheres.

M. Cornet, another Belgian engineer before referred to, published at Mons, in 1875, a remarkable work on compressed air, in which he gives the relative volumes of a given weight of air at a constant temperature, and the increased temperatures due to compression, for a range up to fifteen atmospheres. A M. Mallard has also written a paper, entitled "A Study on the Theory of Compressed Air Machinery," in which a great deal of information is contained.

The most complete work on the subject yet published, so far as the author is aware, is in French, and is by M. M. A. Pernolet Ingenieur, it is entitled *L'Air Comprimé et ses Applications, Production, Distribution, and Conditions d'emploi.* He obtained a copy of it in the French Court of the Garden Palace Exhibition, in 1879-80. M. Pernolet was sent by a French company to study the use of compressed air in England, Austria, Belgium, and other countries, and in 1876 he published his exhaustive work, There is also a small book in Van Nostrand's science series, on " The Transmission of Power by Compressed Air," by Robert Zahner, M.E., New York, 1878, and some information in the latest edition of D. K. Clark's rules and tables. From these several works the tables A and B been have compiled, which show at a glance the theoretical conditions which attend the compression and use of compressed air. It will be observed, on reference to table A, that when air is compressed with increase of temperature, say to four atmospheres, the volume instead of being ·25 is ·374 of its original volume, the temperature having risen to 330 degrees Fahr., and that the work to compress a cubic foot, instead of being 2909 foot pounds requires to be 3618 foot pounds, the difference representing loss of work. Further, at eight atmospheres the volume instead of being one-eighth the original, becomes ·229, or nearly one quarter, and the work for a cubic foot 6021 foot lbs. instead of 4370. At a little over ten atmospheres the temperature rises to 600 degrees Fahr., or that of melting lead, and the relative volumes with and without increase of temperature are nearly as two to one. This increase of heat and volume is also shown by the diagram, Figure 4, where the black line is the actual diagram taken by the indicator, the red line is the isothermal or Marriott line, and the blue line the adiabatic curve, or the line that would be followed if some of the heat was not conducted away during the operation of compression. Figure 4 is taken from a Sommeiller compressor with hydraulic piston, and Figures 5 and 6 are from the high and low pressure cylinders, 11 and 18 inches diameter, of a compound compressor, designed by the author for specially economical working. In this compressor a surface condenser is introduced between the two stages of compression, the air compressed one stage is thus brought down to atmospheric temperature before it receives a second compression, and you will observe how close, for this reason, the black, or working, line keeps

to the red, or isothermal one, and how the loss of power is thus reduced.

One of the best illustrations of the effect of sudden compression of air is the pneumatic syringe. In this apparatus a piece of German tinder, or cotton saturated with bi-sulphide of carbon, is placed in a syringe and a sharp blow that drives down the piston and compresses the air is productive of sufficient heat to ignite the contents. In the same way the American gunpowder pile driver operates, where the fall of the ram by driving a piston into a small mortar so compresses the air as to generate heat sufficient to ignite another charge of powder to again drive up the ram. In the table A it maybe seen how this increased temperature is dependent on the ratio of compression, a point important to impress on you as we have presently to consider a low pressure system that is designed to avoid this disadvantage.

After compression we come to the storage of the compressed air, and it does not require any demonstration to show, that such of the heat above atmospheric temperature as is not conducted away during compression, will be rapidly dissipated through the metal of the storage reservoirs and the pipes conveying it to the air engine, and thus by the time it is used it is again reduced to atmospheric pressure and to the volume that would have resulted if the action in the compressor had followed Marriott's law. The difference in heat and power being a dead loss.

We come now to the use of the compressed air in the air engine, and as in the compressor the temperature rose, so by expansion in the air engine does the temperature fall, and as this fall of temperature brings about a corresponding diminution of volume, we have here another loss of power. So intense is the cold that is soon produced by the expansion of air, that, unless some heating appliances are used to prevent the moisture in the air from freezing in the exhaust passages of the engine, the possible range of expansion is kept within very narrow limits; for instance, the freezing point of Mercury is reached at a theoretical expansion of a little more than one to two, and in a tenfold expansion the temperature falls from + 62 degrees Fah., to —193 degrees. This is best illustrated by a reference to table B, which shows at a glance how much greater are the losses by expansion (as they are in compression), when dealing with high pressures. This table also shows that the advantage of

expansion, as compared with working the whole cylinder at full pressure, is of much less importance with low pressures of air.

From a comparison of columns five and nine it will be seen, that in working with air at a pressure of two atmospheres, the relative efficiency is thus, 82 per cent. if admitted the full stroke, as against 85 per cent. if expanded down to atmospheric pressure ; and in column 11 the ratio of these results is shown to be as ·95 to 1. But with a pressure of ten atmospheres the relative degrees of efficiency are as ·510, if admitted the whole stroke, compared with ·739 when fully expanded. The non-expanded air in this case giving only 69 per cent. of the work yielded by full expansion instead of 95 per cent. as was shown at two atmospheres. Thus you see that as the loss at high pressures becomes greater, so does the necessity for employing grades of expansion become greater, and to carry this out in practice, heating of the air becomes absolutely necessary.

The theoretical losses by compression and expansion having been now pointed out separately, it is found that, when united, they amount to about 60 per cent. of the whole power in a system working at five atmospheres absolute, and to 65 per cent. at eight atmospheres absolute. In order to keep down the rise of temperature during compression M. Colladon introduced the system of injecting water into the compressor during work, and the saving which is thus effected is shown on table A, by comparing columns 9 and 13 for the temperatures with columns 15 and 16 for the work done. The Colladon compressor, called also the wet compressor, is in many respects the best, but it is not always applicable, as, for instance when dry air is required, or when illuminating gas is to be compressed. The compound compressor from which the diagrams Figs. 5 and 6 were taken, does not require water injected. It is made in accordance with a patent that the author took out some six years ago, for dry air refrigerating machinery, and as a contrast to the result shown by those diagram curves, he knows of a compressor now working in Sydney that only gives 33 per cent. of the theoretical results it should do, principally owing to the heat not being got rid of. We come now to table C, which is compiled from the results of some experiments made for Sir George Elliott, at the Powell Duffryn Collieries, North Wales, with machinery made by Messrs. J. Fowler and Co., of Leeds, and recorded in the proceedings of the Institution of Mechanical Engineers for 1874.

TABLE C.

AIR COMPRESSORS AND COMPRESSED AIR ENGINES.

Powell Duffryn Colliery, England.

RESULTS OF TRIALS.

	Pressures in lbs. per square inch.				
Effective pressure of air in receiver ...	40.0	34.0	28.5	24.	19.
Effective mean pressure steam cylinders ...	26.3	25.1	21.5	19.7	16.6
Do. do. compresser cylinder	24.0	22.7	19.5	16.5	14.5
Speed piston per minute (feet)	190	155	140	110	60
	lbs.	in.	in.	in.	in.
Effective mean pressure air engine ...	35.6	29.8	24.7	21.0	17.
Speed piston per minute (feet)	108	104	104	108	88
	Indicated horse powers.				
Compressor steam cylinder (A)	59.4	46.2	35.8	25.8	11.8
Do. air cylinder (B)	52.6	40.7	32.2	21.7	10.1
Air engine cylinder, h.p. (C)	18.3	14.7	12.2	10.8	7.1
Do. brake, h.p. (D)	15.3	12.5	10.2	9.0	5.4
Efficiency at the several pressures.	Per centages.				
B. in parts of A	87.7	88.0	89.8	84.3	85.4
C do. A	30.8	31.8	34.1	41.9	60.8
D do. A	25.8	27.1	28.5	34.9	45.2

NOTE.—The relations of A to B and A to D are dependent on the efficiency of the steam engine and air engine as machines apart from the use of compressed air.

The proportions of A to C are the most important, and shew that with the low pressure of 19lbs. of air, 60 per cent. of the power of the compressing engine appears in the air engine, while with 40 lbs. there is only one-half this efficiency.

According to Mr. D. K. Clarke the relative theoretical efficiencies of a compressed air system working between two and ten atmospheres are as follows :—

For ratios of pressures or atmospheres	2	3	4	5	10
The final temperatures for compression are	178°	258°	321°	373°	359° Fah.
The reduced efficiency of expanding from 62 deg. Fah. ...	82.	73.	67.	63.	51. p. cent.
And loss of efficiency	18.	27	33	37	49 ,,

As in the use of compressed air, there is the compressing engine and the compressor interposed between the power engine and the motive power (whether it be steam or water), the efficiencies of these engines are factors in the efficiency of the whole system.

If we take the efficiency of the compressing engine or turbine at 80 per cent., and that of the compressor at 80 per cent., then the combined efficiency is $\frac{80 \times 80}{100} = 64$ per cent. 64 per cent. of 51 (the percentage for 10 atmospheres) is 33 per cent.; and similarly the percentage for two atmospheres is 64 per cent. of 82 per cent. = 52 per cent. The less the degree of compression the greater is the efficiency, because there is the less loss from dissipation of energy through the intermediate reduction of temperature.

In general practice the resultant efficiency at the pressures used, does not often appear to exceed 30 per cent., but the advantages of using compressed air are so great that if 90 per cent. instead of 70 per cent. of the power was lost it would be still desirable to employ the air system. One great point of contrast between the use of air and water for the transmission of power is that no return pipes are required for air; the compressor takes in its supply from the atmosphere, and the air engine exhausts again into that great general reservoir, with the attendant advantages of ventilation and cooling.

You are perhaps aware that in London, Hull, and other cities, water power at 700 lbs. per square inch is supplied by companies through street mains, and is laid on to workshops and warehouses. At Birmingham it has been proposed to supply compressed air for the same purpose on account of its many advantages. In the case of domestic hydraulic motors, the nuisance from leaky water pipes and the difficulty of dealing with a pressure of 700 lbs. would keep it out of most houses, but if compressed air was laid on, a few shillings would purchase an air motor that would drive a sewing machine, knife cleaner, or other household appliance, such motor would cause no trouble from mess or dirt, and would ventilate and cool the apartment in warm weather.

For the purpose of hoists, small trade appliances, and such machinery, air, owing to its elastic properties, would be used in proportion to the work to be done; one-half volume only being used for one-half work, whereas with hydraulic machinery you use the same power whatever the load. For the conditions of Sydney a system of compressed air supply should be well adapted, and would be found much cheaper than the gas engine and hydraulic system now coming so much into use.

In connection with the transmission of power by compressed air there is the important question of the friction of the pipes or canals

to be considered. This can be calculated theoretically, and is also known from the experience gained with miles of pipes in the great Alpine tunnels. The author obtained data personally from the contractor for the great water tunnel, under Washington, D.C., U.S.A., whither he went on purpose, and there saw four large Ingersoll Compressors at work on the undertaking. It is fortunate for our purpose that the friction of air does not increase as the density, and the loss does not make a great item. The results of experiments carried out by the Piedmontese engineers at Mont Cenis give results as follows:—

Length of Pipe 1000 Metres or 3280 Feet.

Velocity in Pipe per second.	Diameter of Pipe in inches.					
	4	6	8	10	12	14
	Loss of pressure in lbs. per square inch.					
1 metre—3.28 feet	.114	.076	.057	.57	.038	.038
2 ,, 6.56 ,, ...	.500	.343	.250	.210	.172	.153
3 ,, 9.84 ,, ...	1.183	.800	.592	.477	.394	.343
4 ,, 13.12 ,, ...	2.060	1.374	1.030	.840	.687	.600
5 ,, 16.40 ,, ...	3.200	2.160	1.160	1.290	1.100	.923
6 ,, 19.68 ,, ...	4.446	3.964	2.223	1.778	1.482	1.280

These figures shew approximately that a flow of six metres or about 20 feet per second will pass through 1000 metres of a four inch pipe with a loss of say $4\frac{1}{2}$ lbs. pressure, 6 inch pipe with loss of 4 lbs., or through an eight inch pipe with a loss of $2\frac{1}{4}$ lbs., which is equivalent to say, something over 7 lbs. 6.4 lbs., and $3\frac{1}{2}$ lbs. respectively in a mile. Now 20 feet of air per second, at 120 lbs. per square inch through a 6 inch pipe means, even without expansion, approximately 120 horse power, and taking 7 lbs. deduction it gives less than 6 per cent. loss by friction to transmit it a mile through a six inch pipe. The table shews how this loss decreases with the enlargement of the pipe; the friction really increasing as the square of the velocity or inversely as the diameter of the pipe.

Enough has, perhaps, been now said to give a fair idea of the principal advantages and drawbacks which attend the practical application of compressed air, and it has been shewn that in order to carry stored air in tramways, so that long distances may be travelled without recharging, great pressures are necessary with all their attendant losses and complications. In spite of these drawbacks, however, very great progress has been made in the application of compressed air as

the motive power for tramways, and the success which has already attended its use has prepared the way for the third part of my subject—

SOME RECENT IMPROVEMENTS IN THE APPLICATION OF COMPRESSED AIR.

to which your attention is asked, as they are, perhaps, destined to lead to further extensions of compressed air machinery, especially as the motive power on tramways.

Owing to the great cost of cable tramroads, both in first construction and subsequent wear and tear, an engineer of San Francisco, Mr. George Pardy, was lately led to look around for some equally effective, but less expensive system. The city of San Francisco may be said to be the cradle of cable road development, and it still has the greatest number and most successful roads at work on that system, but that does not necessarily shew that they are adapted for all conditions of service. Mr. Pardy, after making himself acquainted with what had already been done in the application of compressed air, and with the drawbacks under which the then existing systems of air tramways laboured, conceived the idea of abolishing the enormous pressure and the heavy reservoirs heretofore used altogether. He then worked out an entirely new system, which consisted in providing every car with a small pair of engines, and with light reservoirs to carry the air at a moderate pressure only, but in sufficient quantity to propel the car for a short distance, say, from a few hundred yards to a mile. To make the system complete an air main is laid from the compressing engines the whole length of the tramway, and at suitable intervals along the road special valves are placed on this main, which valves are accessible through small openings in the surface of the street. The driver on each car is furnished with a short flexible hose, attached at one end to the reservoirs, and at the other end provided with a nozzle; this nozzle is so constructed that when it is inserted into the street valve, an instantaneous connection is made, and a re-charge of the reservoir from the pressure in the main pipe takes place. It has been proved in practice that this can be done in less time than it ordinarily takes to set down or take up passengers.

Mr. Pardy sold his patent right for the State of California to the Risdon Iron Works Co. of San Francisco, and this company constructed a trial car, which was run experimentally in the streets of

that city during the time the author was there, about May, 1884. It was noted that when the car was in the shop near to the main pressure reservoir, a charge of about 80 cubic feet, and up to 120 lbs. pressure could be taken into the car reservoirs in about five seconds; and when the air was led several hundred feet through a $1\frac{1}{2}$ inch tube, and a length of $1\frac{1}{4}$ inch hose, so as to charge in the street, the author timed the charging himself on several occasions, and found it to averge only 30 seconds. The efficiency of the whole machine was so great, both as to weight carried, and distance travelled, that it created quite a stir for a time by its success, and had it not been that San Francisco was in possession of what is, perhaps, the most complete tramway system in the world, and had seven or eight separate cable roads already constructed, at a cost of some millions of dollars, it would long since have been in operation there.

In order to make a comparison between the merits of Mr. Pardy's tramway improvements and the systems before in use with compressed air, we will take that of Megarski first, because that appears to be the best known, and secondly, because up to the present, it has had the largest measure of success. Sir F. J. Bramwell examined into and reported on the Megarski system at Nantes, in France, after it had been in regular work for three and a-half years, and he read a very favourable account of it before the Mechanics' Section of the British Association at the Southampton meeting, in 1882.

It appears that the fuel used for the compressing machinery at Nantes amounted to 1.74 lbs. of coal per ton gross of the car weight per mile run, whereas Merryweather's engine did a ton mile with ·69 lbs. of coal. And drawing conclusions from this, Mr. D. K. Clark, in his last volume on Tramways, says, "whilst such a *contrast* can be maintained, it needs but little argument to prove that the direct steam-powered tramway engine is, as it ought to be, the more economical." Now the author is bold enough to differ with Mr. Clark, for the simple reason that coal consumption is only one factor out of many in estimating the economy of a tramway, and if the cost of motive power was the same in both cases, there would still be no reason why the permanent way should have the extra wear and tear due to carrying the additional weight of the boilers and fuel about when they could be left stationary ; but the comfort of the passengers, the absence of smoke, smell,

and steam, are all points affecting the *economy* of the working. Suppose now, however, we make the contrast under the fresh light let in by Mr. Pardy. The Megarski cars, built for the Caledonian road service of the North Metropolitan Tramways Co., London, carry 40 passengers, have their reservoirs strong enough to carry a pressure of 450 lbs., and weigh from $6\frac{1}{2}$ to 7 tons empty, or say 9 to $9\frac{1}{2}$ tons loaded. A low pressure car of about the same dimensions, and as shown on figures 1, 2, and 3, to carry, say, 110 lbs. pressure, will not require reservoirs of more than one-third the weight of those that carry 450 lbs, and the hot water vessels, with the contained water, will be dispensed with altogether. The car, on the Pardy System, can thus be reduced in weight to about four tons, empty, and say $6\frac{1}{2}$ tons loaded. That is to say, about 70 per cent. of the weight of the high pressure Megarski car, at nine tons loaded, and a little over 60 per cent. when lightly loaded. The maximum pressure in the low pressure reservoirs will be nine atmospheres total, and the engines will work at from 15 to 30 lbs. above the atmosphere, instead of being used at from 75 to 90 lbs., as in the Megarski Car, and from what has already been shown, as per table B, about the larger relative efficiency when working with low pressure air, an ultimate efficiency of 40 per cent. should be attained in the low pressure, as against 30 per cent. in the high pressure car. That is to say, the efficiency in the Megarski system is, probably, only 75 per cent. of what may fairly be expected from a low pressure one. As the relative weights are taken as 70 per cent., fully loaded, and 60 per cent. light, a mean estimate of 65 per cent. is fair for the proportion that the gross weight of the low press car bears to the gross weight of the high pressure one, and the relative power required for the same weight being 75 per cent., the actual power becomes $\frac{75 \times 65}{100}$, which gives 48·75 per cent., or *less than one half* of the power for the low pressure car of that is required with the higher pressure one.

Against this great advantage has, of course, to be set the fact that the low pressure car will only run, say, one third of the distance with a charge of air, and there is the cost of laying mains, with the loss by leakage and friction, but there will be no wear and tear in the mains to speak of, and the low pressure machinery will be much simpler to make and less expensive to keep in order, so that I have no doubt any intelligent 'bus driver would soon be able to

manage a "Pardy" car, instead of requiring highly skilled men for the work.

For the purpose of quickly charging the car reservoirs from the street mains a number of valves have been designed, some of them in San Francisco and several by the author; and doubtless many more will shortly be forthcoming. Figs. 7 and 8 are reduced from full-sized drawings ofthe valve shown in figure 2, section of car. In this A is the main, B is a stop-valve, C is a brass nozzle, which is wired on to a flexible hose, the other end of which hose is connected to a retention valve on the car reservoirs, DD are double beat valves, which are lifted by the conical end of C after it is passed through the packing rings of the main casting, through the intervention of the roller and lever shown. Before C is withdrawn the valves DD again close. It will be seen at once that the air passing from the valves through the slots in C have no tendency to drive it in or out of the casing. Mr. Pardy does not propose to cover the small holes in the street, but the author has enclosed the whole of the valve arrangements in a large cast iron vessel which can be easily cleaned out; it is provided with a heavy cover which further has a small hinged lid to the air-pipe opening so as to keep out dirt. It is not desirable to say more about this valve now as the paper is already extended to a greater length than was intended, but you will no doubt understand its action and see that many obvious modifications are possible all for the same object; it is nothing more than a variation of the coupling used for the air brake pipes, in fact there is really no absolutely new feature, taken by itself, involved in Mr. Pardy's system at all, for it is based on practical experience already gained in separate branches of engineering work, but Mr. Pardy has so brought these several separate parts together as to construct from them an entirely new application of motive power for tramways.

Up to the present time the designers of compressed air tramways, not having any idea of charging by the way, have principally exercised their inventive faculties in seeking to increase the distance that can be travelled with one charge, and in doing this, pressure has been raised, and the capacity and weight of the reservoirs on the engine or car increased, as already pointed out, until the proportion of dead weight to payable load has become excessive; but by the introduction of an air-main, with valves along the route every few

hundred yards, a means is now provided that will enable the minimum of non-payable load, and the maximum of efficiency to be attained.

If large compressing engines of 500 horse power were erected in a favorable situation for getting coal and condensing water they should obtain an efficiency as prime movers at least twice as good as the present tramway locomotives, and with air cars there should not and need not be more than one-half of the present average dead weight per passenger to put in motion. In such a case the same work in passengers carried, could be done with the same fuel as is burnt now, if the ultimate efficiency of the air engines on the cars was only 25 per cent. of the initial power, that is if 75 per cent. was lost. For reasons already pointed out, however, a much higher efficiency than this 25 per cent. should result with the low pressure. But surely if the coal bill was 20 per cent. greater than now instead of less, it would be warranted by the gain in comfort, convenience, and cleanliness, in the absence of steam, smell, and smoke, and in the running of light, handy, and smart cars at much more frequent intervals, and in the reduced wear and tear of permanent way, that would result from the substitution of compressed air cars in place of the present lumbering roadway destroyers, with their enormous loads, inconveniences and dirt *ad nauseum.*

It would be well for a few minutes to again direct your attention to the proposition recently made in Birmingham, England, for supplying compressed air from a main as motive power for machinery in warehouses, small shops, or for domestic motors. For this purpose air has many advantages that do not apply to hydraulic power, no return pipes are required for the exhaust air, which by expansion can be brought down to intense cold, and after doing its work would serve as a refrigerator if conducted into a proper chamber. Owing to the expansive property of air just so much is used as is required to do the work instead of as in hydraulic systems, a full power being used whatever the load. Compressed air, unlike steam, does not condense in the pipes, but like steam it is independent of differences of level. You could take up a supply from an air main to wind a clock in the highest cathedral tower, or down to work a coal hewer in the deepest pit, without any practical difference in the results. The case would be very different where hydraulic pressure is used. The author was down the great Comstock mine, in Virginia City, to the 2900 feet level, and the water conducted down there to work hydraulic pumps from 400 feet above the surface gave 1400 to 1500 lbs. pressure per square inch,

due to the difference of level. At the same time the compressors were sending down air to work machinery at practically the same pressure below as above.

If a company were to start in Sydney to supply compressed air to work elevators, sewing machines, and the thousand and one appliances that are now worked in the city by hand power and by little kicking and often dangerous steam engines, what a convenience and saving in cost and worry would be affected, a saving that would many times compensate for the mere loss of power between the source and its application. In the great Derby shops of the Midland Railway Company compressed air is used, and the author saw the cylinders of a locomotive being rebored in their places, the power being supplied from a little air engine cramped on to the frame, and supplied with air through a rubber tube. It is used for cranes at Portsmouth Dockyard, and a factory at the great Seraing Works has all the cranes worked by air.

The application of compressed air to torpedo work is quite a modern development, and the pressures used go up into the thousands, but its consideration is rather beyond the object now in view, and the author would like to conclude this paper, already longer than he had intended, by drawing some comparisons between the present tramway system of Sydney, the cable roads of San Francisco (that we hear so much about), and the Pardy low pressure air system. First, however, your attention is asked for a short time to an application of compressed air in connection with hydraulic elevators, which is called

THE HYDRO-PNEUMATIC ELEVATOR.

The necessity for applying elevators to the lofty buildings of this city is now pretty well understood, and the advantages of hydraulic power for the purpose is duly appreciated. A large experience in hydraulic elevators and an examination into their details and construction as carried out in the principal cities of America and Europe has proved that moderate pressures are the most satisfactory in their results, and that pressures up to 700 lbs. are troublesome, work with shocks, and are not to be compared for smoothness of working with pressures of say 100 lbs. or thereabouts.

To get a pressure of 100 lbs. from an open tank, it would require to be up as high as the top of the Post Office tower, and if a loaded accumulator of, say, 30 cubic feet capacity is used, it becomes an

expensive item. In the hydro-pneumatic system a close reservoir of wrought iron or steel is substituted for the tank or loaded accumulator, and the water is pumped into this reservoir against an air pressure equal to the head required. The air in the accumulator can be let out easily if less pressure is wanted, or more air can be put in by opening snifting valves in the pump if more pressure is wanted, and thus for special cases the attendant can command a higher pressure than that used for ordinary work. The variation of the pressure during the use of the water is, of course, dependent on the proportional volumes of air and water in the reservoir, and the proportion of the pump power to the elevator work. The reservoir may be made large enough to store a great number of lifts if required. This reservoir is, of course, nothing but an enlarged air vessel, to the pump, but as arranged for an accumulator it greatly simplifies and cheapens the cost of a hydraulic elevator, and besides it can be made of any shape, and can be placed horizontally or vertically, so as to be got in the least valuable space available. I need scarcely say that with the compressed air accumulator the loss by friction of packing is done away with. I hope shortly to be able to invite members to see one of them at work. Fig 12 illustrates the new application to an elevator.

Comparison of Three Systems of Tramway Propulsion.

The rival systems of motive power for tramways most likely to be brought into competition with the low pressure pneumatic system that the author has attempted to explain this evening, are—First, The cable roads as so successful in San Francisco; and Secondly, Our present steam locomotive arrangements

A great deal is often heard about the cable roads of San Francisco, and it has been put forward that they are just the thing for the requirements of Sydney. The author knows this city well, and he has had every opportunity of becoming acquainted with the tramway system in the capital of the Golden State, both by observation and description; the result is, that he yields to no one in his admiration of the skill and ingenuity of the engineers, as well as of the enterprise and foresight of the capitalists, that has led to their mechanical and financial success, but Sydney is not San Francisco, and the conditions that apply to tramways in these two Queen Cities of the Pacific are altogether different.

Firstly, the cable roads in San Francisco have grades as steep as one in five or six, to work up which, no ordinary locomotive, whether air or steam propelled, would be suitable. The six principal cable roads rise over hills from 250 to 300 feet high, and in several cases pass over two such hills in their run. The latest road up Telegraph Hill is, it is believed, about one in three, and only wants tilting a little more when it would not be a tram-road at all, but an elevator, and for such conditions as these, the author knows of no system so suitable as the cable ; but although Sydney is a hilly city, as cities go, we have no grades on our tram-roads that locomotives cannot climb, and thus the first motive for a cable road does not exist.

Secondly, the cost of cable roads is very great in construction, maintenance, and working expenses. This, in itself, would be no objection if the conditions for great earnings were commensurate ; but in San Francisco the conditions do not as they do here present seven or eight suburban tram lines, all converging to one focus, and then, figuratively speaking, running strangled together down a side street to a terminus in a back yard nowhere. Unfortunately for us, through the physical configuration of Sydney, we have something of that kind here. There the streets are straight, each cable road has its terminus in a populous centre of city traffic, and it runs out through main streets which correspond to our George, Pitt, York, King, and Park streets, but on a much larger scale. The tram lines there command also separate avenues of intramural traffic, such, for instance, as is carried in Sydney by the Railway omnibuses, and they also perform the greater part of the work that is here done by our suburban railway. There is thus an enormous traffic, and one much more uniform throughout the day than we have here, owing to so many of their leading business streets being traversed by the tramways.

Thirdly, it has been estimated in San Francisco that cable roads cost at least five times as much to construct as horse tramways, and three times as much as a road and air main for the pneumatic tramway. In the case of the cable it is in constant motion, with its supporting pulleys, and wear and tear is going on whether one car an hour or one car per minute is the service on the track. With an air main there is no wear and tear proper, and no more depreciation than belongs to an ordinary gas or water main.

Fourthly, the cable roads consume a large portion of the power exerted, to work their own destruction in the wear and tear of cable, which constitutes such a large proportion of the dead weight or non-payable load. In an able paper on the cable roads of San Francisco, read by Mr. Hanscom before the Technical Society of the Pacific Coast, the average working of seven principal cable roads is summarised thus :—Out of the total power exerted by the engines, 68 per cent. goes to move the machinery and cable, 28 per cent. to draw the cars, and 4 per cent. only to carry the passengers. If you give any consideration to these four points in the cable system just referred to, you will, probably, like the author, conclude that the conditions for its successful adoption in Sydney do not exist, and so we will next proceed to consider the system we actually have in use.

Under existing arrangements here in Sydney we commonly have a 16 ton locomotive drawing two cars of a weight aggregating eight tons, and sometimes ten tons, or collectively say 24 tons of dead weight in a train.* And although for an hour or two at morning and evening, the cars may be crowded, yet on many lines the average throughout the day is said to be only about 20 passengers. As a basis for comparison, and to give our present system every chance, we will take 45 passengers instead of 20, as the average load, then at 15 persons to the ton, the live load will be 3 tons, which, added to the 24 tons dead weight, makes the total load 27 tons. That is to say, *make the best of it, and then only* 11 *per cent. of the power is exerted to move the passengers, and* 89 *per cent. is required to drag the dead load about*, and DESTROY THE PERMANENT WAY.

Lastly, under the pneumatic system, where light cars at frequent intervals are proposed, we take for comparison a London metropolitan horse car for 40 passengers, which weighs $2\frac{1}{2}$ tons, if to this is added one ton of reservoirs, &c., and half a ton of engines, &c., the weight ready for work becomes four tons. Assume it to be only half loaded, or with 20 passengers at 27 cwt. (we have taken 45 for present system, remember), the total running weight would be 107 cwt. Of this gross load the 27 cwt. of passengers would be just over 25 per cent., instead of being only 11 per cent., as in the present system with 45 passengers; but if we consider the air car as fully loaded,

* During discussion said to be nearer 30 tons.

or with another 27 cwt., making a total of 6 ton 14 cwt., then the proportion of useful effect or payable load rises to over 40 per cent. The light air cars can be started every half hour, every ten minutes, or every minute, according to the requirements of the traffic, and if they are made to carry no roof passengers they can be managed with only one man to drive and collect fares, as is done with the bobtail cars used in some cities. Looking at all these points, The author thinks no hesitation can exist as to the advantages of air cars over our present system. As regards speed, the cable cars cannot run over say seven to eight miles per hour, but the air cars have besides the advantages already enumerated, the further one that they can "make up time" when on less busy parts of their route, as any reasonable speed is possible.

The question of the adoption of the pneumatic low pressure system has been under consideration by the City Railroad Company, of San Francisco, and the following extracts are taken from a copy of their engineer's report (Mr. W. H. Milliken). After considering horse power, cable, electric, coal, gas, high pressure air, and the Pardy system, Mr. Milliken says :

" The Pardy system is an improvement upon the high pressure systems in the following very important particulars :

1st. As it is operated with a low air pressure not exceeding 100 lbs. per square inch, the air may be compressd at one operation in a single machine, instead of progressively in several, as in the high pressure systems, thus saving the original cost of, and power necessary to run these additonal machines ; also at this low pressure the proportional useful effect is much greater.

2nd. It permits the adoption of light-weight motors, having small air receivers not exceeding fifty cubical feet in their combined contents, so that your present road-bed and track will amply sustain them, and the power required to move them will be much less.

3rd. It permits the replenishment of the air to recuperate the power of the motors at any point on the line, so that at every starting the motor may exert its maximum power.

4th. In its adoption, the system involves less expenditure of capital in providing motors and compressing machinery, and avoids the cost of replacing your present road-bed.

5th. *It would be less of an experiment mechanically* and financially, offering no risk whatever in its adoption.

6th. It permits the application of the machinery and motive power upon your present form of car, without encroaching upon the space reserved for passengers. It improves upon the cable system in the following points:

1st. It can be put in operation on your line at about one-fourth the cost.

2nd. It can be operated at about 30 per cent. less expense.

3rd. It is never liable to get out of order to such an extent as to suspend traffic.

4th. A better schedule time may be made, and at least one car on your main line dispensed with without interfering with the service.

5th. It may be operated on your branch line on Sutter street, and on any future branches running on streets already having cable lines.

6th. It can be put into operation without interfering with your present traffic or disturbing your road-bed.

7th. It involves no financial experiment, as its daily running expenses including interest on new capital invested in applying the system, will not increase your present expenses, but will rather materially decrease them.

It is better than the electric system—

1st. Because it will not cost over one-third the money to put it into use.

2nd. The daily expenses will be about 20 per cent. less including interest on capital invested.

3rd. There will be no disturbance of your present road-bed.

4th. It will not be affected by storm water, which, in the electric system, will at times flood the underground tubes and destroy insulation, and suspend the operation of the whole line."

The following table exhibits what is offered as an approximate estimate of the cost of constructing and operating each system, exclusive of such items as taxes, licenses, engine house or stable rent, drivers and officers' salaries, etc., for these items being common to all systems, they may be omitted without impairing the accuracy of the comparison.

COMPARATIVE TABLE.

SHOWING THE COST OF PROVIDING AND OPERATING VARIOUS SYSTEMS.

System.	Main Line.		Branch Line.	
	Cost of Providing.	Daily Expenses.	Cost of Providing.	Daily Expenses.
	Dollars.	Dollars.	Dollars.	Dollars
* Horse Power	50,000	150 00	21,250	63 75
Cable	450,000	203 00	Not	available
Electric	375,000	165 00	Not	available
Coal Gas	130,000	200 00	45,000	120 00
High Pressure Air	175,000	164 00	66,000	55 00
Low Pressure	105,000	125 00	40,000	53 00

Slight variations in small details may exist between Mr. Milliken's views and the author's; but on the whole he so thoroughly puts the case that it hardly needs an apology for so lengthy an extract from his report. A pneumatic tramway in San Francisco, however must not be expected for some time. That city is the home of capitalists and stockholders who own the cable roads, and the cable road patents throughout the U. States. In this stock millions of dollars are invested, and such great interests must be all against a rival system. We do want the best system for this city, and the object of the author has been to find the best system for our wants. If the Pardy pneumatic tramway will stand the criticism of this Association. then the inventor should have a chance to see his cars running here before long.

In conclusion, our present tramway system is doomed. It arose under exceptional conditions, and the cry for more means of conveyance in our rapidly extending city and suburbs did not admit of a waiting for experience. After travelling and seeing the principal tramways in America and England, the author considers the low pressure air system is the best one to take its place, and thanks you for your patient attention to a rather tedious paper.

* The horse power system provides for bob-tail cars with only a driver; all the other systems provide for cars of double the capacity with a driver and conductor

DESCRIPTION OF ACCOMPANYING PLATES.

Figures 1 to 3 represent four views of a compressed air tramway car designed to carry 40 persons. It is fitted with starting, regulating, and brake gear at each end so as to require no turntable at end of journey. The inside cylinders are arranged to work in a dust-tight box, and the whole engine can be detached for repairs, and another one substituted by the removal of sixteen bolts. The crank shaft is geared, 2 to 1, on to the main axle, and the proportions of cylinder are such as to take a full load of 40 persons up a grade of 1 in 20, with 25lbs. pressure of air. The air is stored at about 100 to 120lbs. pressure in the eight reservoirs marked D to K, on figure 3. Those marked D F G H I J K are connected by small pipes, forming practically one reservoir, while the cylinder E has separate connections, and serves as a reserve for emergencies. The cylinders are supplied from the reducing chambers, marked B in elevation and plan, they are placed on the platforms, and the air in them is reduced to working pressure from the pressure in the cylinders by the valve shown in figures 9, 10, and 11. The pipes L L connect the main reservoir or battery of cylinders with the three way cock on B B, and the reserve store of air is connected by pipes M M. The working pressure is regulated by the hand-wheel and spring on top of valve. Should a little extra pressure be needed to start the car near the end of a journey, when the main reservoirs are low, the driver can, by means of the three way cock, give temporary extra power to get under way. The charging nozzle, and flexible hose is shown hanging to the platform rail in elevation, and connected to the street valve in figure 2 or end view.

The diagram, figure 4, is from a Sommeiller compressor, and is taken from Pernolet. The diagrams 5 and 6 are from a compound compressor designed by Mr. Selfe to work up to 120 lbs., and fitted with a surface condenser between the stages. It will be seen, on examination, that all the heat of the first compression is removed before the second stage begins, and the working line keeps very close to the isothermal line. The cylinders are water jacketed, but no injection of spray was used.

Figures 7 and 8 are section and plans of a street charging valve, the large cover fitted with wood blocks end grain. The double-seated valve is opened by the conical end of the nozzle pipe on hose marked C.

Figures 9, 10, and 11, show the reducing valve and regulating cock to chamber B, before referred to. It will be seen from the construction of the valve that the pressure of the spring determines the pressure in the chamber, irrespective of the greater pressure in the reservoirs, and thus keeps it constant, as the main supply is reduced from say 120 lbs. to the minimum or working pressure.

Plate 3 shows in figure 12, the machinery of an elevator with a hydro-pneumatic accumulator. The pump draws a supply of water from the square tank by pipe S, and pumps it by pipe D into the accumulator against a pressure of air. By the operation of the valve V the water under pressure passes by pipes P and C from the bottom of the accumulator to the elevator cylinder, to lift the car, and by pipe W and C from the cylinder to the waste tank to lower the car.

By the action of a self-acting regulating valve the pump works up to the required pressure and then stops, it starts again as soon as the water is drawn off for a lift.

The sections of the Sydney and San Francisco tram-roads are drawn to the same scale, in order to show by comparison the great difference in the grades.

DISCUSSION.

Mr. Pollock remarked that Mr. Selfe had had the honor of bringing the subject of air compressing prominently before the members of the Association in his able and interesting paper read at our last meeting, his principal object being to prove that the steam motors used at present on our tram lines would be advantageously superseded by Pardy air motors. Compressed air as applied to motors (above ground) was of comparatively recent date, and it was very difficult to get reliable data with which to compare his statements of the performances of the Pardy motor, so that he would have to draw his conclusions from what was known as to the economy of air when used in other machines. In mining and tunnelling, for working hauling engines, coal cutting machines, rock cutting and boring, and for many other purposes —since 1850 air had quite superseded hydraulic and steam power, its many advantages for *underground* work, outweighing its extravagance

as a motive power. In our own colony the A. A. C. at Newcastle used it in their coal mine, and had a very efficient plant. The pressure that was generally used for these purposes, and which was said to give the best results was about 60 lbs. absolute, or about half the pressure that he understood, Mr. Selfe proposed to use in the Pardy motor—and at that pressure (60 lbs. absolute) the theoretic useful effect was said to be 50 per cent., but the highest practical results did not average more than 25 per cent., and as the pressure was increased, this percentage became less. Mr. Selfe had fully pointed out in his paper the reason of this loss, and there had been many attempts made to decrease it, principally in the line of surrounding the compressing cylinder with water, or injecting water into the cylinder, this of course cooled the air and prevented its expanding with the heat, but of course all the heat extracted was a dead loss. Sir William Siemens suggested that a very perfect arrangement would be to take the water that was used in cooling the air in the compressing cylinder, and inject it again into the expanding cylinder, so that the heat taken from the air during its compression would be restored to it during expansion, by this means if the quantity of water injected were such as to keep the temperature practically uniform throughout the stroke, the whole of the loss at present arising from heating and cooling the air would be avoided. He did not know whether this idea had ever been carried out, perhaps Mr. Selfe might be able to give us some information on this point. In comparing the pneumatic motor with the system we had in Sydney, Mr. Selfe took a London horse car carrying 40 passengers, and weighing (*empty*) $2\frac{1}{2}$ tons, and suspended on it 1 ton of reservoir and $\frac{1}{2}$ ton of machinery; now he thought the horse car would require to be strengthened, and in consequence be heavier, to stand 30 cwt. of machinery fixed to it, or they must be built with a very large margin of safety, and to take this car weighing with passengers 6 tons 14 cwt. up an incline of 1 in 19, at say $3\frac{1}{2}$ miles per hour, would take 8.3 h. p., and 10 cwt. appeared to be very little to develop this power; however this was a matter that no doubt Mr. Selfe had given careful consideration, and he would keep to the figures in the paper. The percentage of live load to gross load was given at 25 per cent. when hal loaded with passengers, and 40 per cent. when the car was full; now when we considered that 75 per cent. of the power originally exerted was lost in compressing and expanding the air, wherever this might be done, and we were only dealing with 25 per cent. of the original power to make a fair comparison, the power exerted to move the passengers along was $6\frac{1}{4}$

per cent. when half loaded, and 10 per cent. in the case of the car being full, it was quite true that the balance of power was not used in destroying the permanent way, but *it was lost*. The above car was compared with two of our present cars weighing eight tons empty, and only credited with 45 passengers, now we did not see any reason that a car merely because it was drawn by a steam motor should be more than three times the weight of one propelled by air, thus allowing the cars to be the same weight for an equal number of passengers, it would bring the percentage of live load to dead load in our present system to 14 per cent. Again Mr. Selfe suggested that one man could drive the car and collect tickets. Presuming they were to maintain the present rate of speed, he thought it would be readily admitted that two men would be necessary, and as a car was only to carry 40 passengers *the wages item* would be considerably increased, not to mention the assistance required to make the connection at the valves for recharging the reservoirs. There was no information given us as to how far the Pardy car would run with its stock of air, and it was well to bear in mind that any derangement of the machinery used for compressing the air at the end of the route would put a stop to the whole of the traffic, and the whole of the cars would remain stuck along the line until the air compressing machinery was repaired. Mr. Selfe asserted that our present tramway system is doomed, now he thought it did its work remarkably well. No doubt there was great room for improvement, especially in the permanent way which was generally admitted to be too light for the rolling stock. About 18 months ago we had some gentlemen who wished to replace our system by horse cars, and they argued very ably in its favour, and proved at any rate to their own satisfaction that it was the only system suitable for Sydney. He thought the pneumatic motor had a much better show than the horse car, which he always looked upon as a retrograde motion. The advantages of the air motor in avoiding all smoke, fire, &c. were undeniable, but as far as we were able to judge, they were more than balanced by the first cost and expense of running, but no doubt this was one of those cases where a pound of practice was worth a ton of theory, and he hoped Mr. Selfe would see his way to get an experimental Pardy car built and try it, and whatever our individual opinions might be on the subject, he was sure he but echoed the wishes of the members of this institution in saying they would render him every assistance and heartily wish him a successful issue to his enterprise.

Mr. Mackay said the Government could not afford to spend any more money on tramway experiments, especially when it was remembered that railways were about the most profitable investment in existence. He pointed out the inconvenience that would arise in the event of the breakdown of a car made on the system advocated by Mr. Selfe, although it appeared to have many advantages, and if a company could be formed to work it, it should receive concessions from the Government. There was a field in Sydney wide enough for the investment of a million of money in tramways, with a prospect of a good dividend. He still adhered to his former assertion that horse-tramways would in nearly all cases be more satisfactory than steam or compressed air tramways.

Mr. Greenwood asked whether any town could be named in which steam-trams were a success. The proof given by English towns was that they did not pay at all.

Mr. Henson said he did not see how the whole of the energy of the air-motor could be converted into heat, as stated in Mr. Selfe's paper. The inference was that the whole of the energy was lost. A cubic foot of air, compressed to one-fourth, would generate sufficient heat to melt brass according to this theory. The science of thermodynamics was one which still required a great deal of investigation.

Mr. Kerlb asked for some information as to the relative cost of the different systems. The question was, Which was the best system? The paper stated that the cost of the cable system was about three and a half times that of the low pressure air system, and he thought this was a considerable difference, considering the cost of the air compressors, laying pipes, cost of cars and machinery, &c.

Mr. Poole said the great advantage of the system under notice was that there was a minimum loss of power from raising and lowering of temperature, owing to the fact that the pressure was a low one. With respect to the Sydney trams, the road was ridiculously weak, and that was one reason why the system was a financial failure. He believed the tramway might be made to pay if it were in the hands of a private company. He had inspected the stream tramway at Birmingham, and he found there that, after deducting for interest and depreciation, rates and taxes for use of streets, directors' fees, &c., the tramways paid. Yet in Sydney the fares were practically double. There was not that closeness and efficiency in the management of our

tramways that there would be if they were in the hands of a company. He also said that if they doubled the cost of wages paid in England, and added 25 per cent. for the fewer hours worked in Sydney, they would account for almost all the loss on our tramways.

Mr. Cruickshank said provision had not been made for duplicating the machinery in the system under notice. This would be necessary in case of a breakdown. One good point about the steam motor was that it was self-contained, and if any accident happened to it the rest of the cars would not be stopped, as would be the case with cable and compressed air tramways. He had been informed that the cost of working the trams in Sydney was about eight times that of some systems in England. It was the cost of labour that was killing our tram system.

Mr. Trevor Jones said it was unfortunate that in reading a paper upon a subject that had only recently engaged public attention the author was generally unassailable, not perhaps because his facts were incontrovertible so much as that he was generally the only one who had made a special study of his subject, and both time and experience were necessary to the critical discussion of his theories. Mr. Selfe had, however, in his paper cleared the road for discussion by presenting his facts and conclusions in so gradual, clear, and systematic a manner as to offer every advantage to his critics should any of us have had the time to digest them. Some years ago he had been party to a discussion on this subject, and it seemed to be an understood thing that to utilise compressed air as a motive power, the motor should carry sufficient air for the journey out and back, and this seemed to entail the conveyance of such heavy reservoirs that the notion seemed not to be sufficiently promising to pursue further. The other difficulty of the loss of efficiency by the radiation of the heat resulting from compression was just touched upon, but as not much was known on this point, and, moreover, as it only added to the other shortcomings, it did not enter much into the discussion. According to Mr. Selfe, M. Megarski seemed to have been among the first to realise the fact that a greater efficiency was procurable by using large reservoirs with low pressures, and to have successfully applied the idea ; but even he seemed to have been wedded to the notion that the reservoir must carry sufficient air for the in and out journey, and that notion entailed the carrying of a large heavy reservoir. The requirements of commerce had brought about a more intense study of the natural laws attending the compression of air

within the last few years, and now we had at our disposal accurate figures whereupon to build up theories and uses, which, if available to Mr. Mort and his coadjutors, might have rendered success in his pursuits less arduous. The production of cold, the ventilation of mines and tunnels, the actuating of rock drills and other machinery at a distance and at low depths, the impelling of torpedoes, &c., &c., all brought scientific thought to bear upon them, and each branch contributed its quota of knowledge for the benefit of further investigation. With these new facts at his disposal, Mr. Pardy observed that air at low pressures returned more of its efficiency in work than that at high pressures, because it did not lose so great a proportion of the heat generated in its condensation, and adopting medium-sized reservoirs in his motors, conceived the idea of having reservoirs along the track fed with compressed air from a central engine by pipes, and of feeding his reservoirs at intervals along the track. Mr. Selfe's quotation of Mr. Milliken's schedule of benefits derivable from its use seemed irresistible, but while it seemed to commend itself to the Sydney authorities as deserving of being experimented upon, it might have shortcomings of which none but those concerned actually in its use knew of. Nevertheless, with the terrible wear and tear brought about by heavy rolling stock running on light roads, it was gratifying to look upon schemes developing which offered relief from this combination of two incompatible conditions. The fact that the car was also the motor, the reservoir of power and also the machinery being disposed beneath the car, secured the benefit that if the car will negotiate all its grades when empty it will do so when loaded, as each passenger brought his weight to induce further adhesion when wanted. It was perhaps a drawback that every car should require such costly attachments, but this was a matter requiring adjustment financially, and Mr. Milliken, at any rate, saw nothing but encouragement here. He had not here pretended to speak critically, for an excellent reason, viz., that his pursuits were not such as to bring him into contact with the subject. His excuse for saying so much must be the interesting nature of the subject.

Mr. Van de Velde remarked :—He regretted very much that he was prevented to be present at the last meeting to hear the reading of Mr. Norman Selfe's paper on compressed air and its application. He had received this morning the advance proof of it, and he read it with great interest, and considered it as a most valuable contribution. After having studied this paper, it seemed to him evident that the Pardy's

low pressure traction system for tramways presented very serious advantages over horse power, cable, electric, coal, gas, and high pressure air systems, and, certainly, if there was no other better system in the world, he thought that the Government ought not to hesitate in substituting the Pardy system for the remarkable system now in use in Sydney and its suburbs. But he was rather surprised to see that in his very valuable paper Mr. Norman Selfe did not even mention the locomotives without fire-boxes of Leon Francq, which were in use in several places in France. They had been adopted by the metropolitan railway of Vienna, by the tramway company of Batavia, and were recommended for the intended metropolitan railway of Paris. It seemed to be proved that the Leon Francq system was the best and most economical in existence, and therefore he did not admit the conclusions of Mr. Norman Selfe's paper when he said that the low pressure system was the best to take the place of the system adopted in Sydney. He was not prepared to-night to go into the details of this system of traction, but if he was allowed he would make this the subject of a lecture for a subsequent meeting, and hoped he would have no difficulty in proving the superiority of this system over the low pressure air system advocated by our learned colleague, Mr. Norman Selfe.

Mr. A. C. Mountain, said :—Although his leisure time had been too short to enable him to study Mr. Selfe's paper as its merits deserved, and notwithstanding that its subject was one on which probably few engineers in Australia could pretend to speak with authority, he felt that it would be but poor recognition of the trouble and time devoted by its author to explaining the principles of *Pardy's Low Pressure Tramway System* if members did not generally express some opinions thereon, and thereby express their appreciation of the exceptionally exhaustive and able paper which we were to-night invited to criticise. The explanation of the practical disadvantages attendant on the use of air under high pressure—involving loss of efficiency, increased dead-weight (to ensure sufficient strength in the reservoirs with no corresponding capacity for extra carrying space), &c.—were all very clearly and convincingly argued out ; and the manner in which, by the substitution of low-pressure engines, these disadvantages were minimised, and other benefits obtained by the use of the latter system was also suggestively treated ; nor was the practical or financial part of the question omitted, as we were told that its application required so

much less outlay than either the high pressure, cable, or electric systems, and that its introduction into this city could be effected without appreciably disturbing the existing permanent way. As we were all aware, the present tramway system in Sydney had not been a success financially, nor did it appear to have been entirely satisfactory if viewed from the popular stand-points of comfort and suitability for city streets. Although this was so, yet, as he before maintained in a previous discussion on the subject of Sydney tramways, it was very doubtful whether the actual loss incurred in working our tram lines was to be entirely chargeable to the "motor" system. The initial error of the work lay in the original use of permanent way in all respects too light for the intended service, which had resulted in continual and costly repairs for maintenance, besides increasing the wear and tear of rolling stock. But, first of all in the item of expenses, came the simple fact that it was a *state concern*, and as such could, not in cost of working and economy of administration, be compared with similar enterprises conducted by private companies, who were so much more at liberty to act as they thought best in the interests of their respective shareholders, untrammelled by undue pressure or influence of Parliament or Ministers. A hint at this part of the question was sufficient, as the effect of such official control was pretty well understood, and needed no amplification. He merely wished to direct attention to the fact that the financial success of a given system of tramway as at present controlled in Sydney was not *of necessity* assured by the adoption of a system that might, under different conditions of management, be worked to advantage. In comparing costs of working different methods, this fact—which was an important co-efficient in the calculation—was apt to be overlooked. Hence his reference to it. He should like to have seen some estimates of the probable cost of each of the light-weight air cars, with the first cost and working expenses of a central station and compression pumps with air mains and valves necessary to feed a service, say, between the Railway Station and Bridge-street. With all the advantages claimed, it still was apparent that each car to carry about 40 passengers must have the mechanism of an engine fitted with reservoirs, &c., and must be rather costly. If an experiment could be attempted at a reasonable cost on one of the metropolitan tram lines, he should hope that the Commissioner for Railways would see his way to authorise it, as it certainly was the possessor of many advantages over the present "motor" system, if only

on the score of absence of noise, dust, grease, and danger to persons driving horses. In establishing a comparison between his system and that of the "cable" lines, Mr. Selfe pointed out the necessity that caused an ingenious American engineer to devise a means of overcoming the abnormally steep gradients of San Francisco, which had hitherto been unattacked by any of the hitherto-practised methods of mechanical locomotion, and drew the inference from that fact that the cable system was only suitable, on account of its cost and the dead-weight carried, for such extreme inclines. This was apparently a very fair deduction, for the first cost of a cable line was undoubtedly heavy, and the wear and tear of wire rope amounted to from 70 to 100 per cent. annually, in our own experience on ordinary work; yet a few months since when he had he opportunity of making a minute inspection of the cable line running from Melbourne to Richmond and Hawthorne, he was surprised to find that notwithstanding the heavy outlay, the line was working so well, and was so popular that the shares of the company were selling at a high premium. The dangers of the cable line practically was the discontinuance of all the traffic on the line when the cable strandted, an event which, he learnt when there, should always be forestalled once the men became efficient, by detection of the weak strand and repairing same during the night. He also observed that the shunting of cars from the "up" to the "down" line was effected by manual pushing, which was not pleasing to the eye; but otherwise there was no doubt that the system was in great favour with the good people of Melbourne, and if Mr. Selfe could introduce as comfortable and sightly a service as our sister city possessed, and at one-quarter the cost, he would assuredly gain the gratitude of all Sydney residents. In any case Mr. Selfe deserved our hearty thanks for the very interesting paper that he had prepared for the Association.

Mr. Shellshear remarked that he took exception to the statement in the paper that "in the compression of air the whole of the energy exerted to effect its compression is converted into heat," the fact being that in the act of compression work was expended firstly in overcoming the elastic resistance of the air, and secondly in raising its temperature. After compression the work expended in overcoming the elastic resistance of the air could be given back as useful work; when the air was expanded in the air engine, the work done in raising the temperature of the air was lost on account of radiation and absorbtion He referred to the hydro-pneumatic elevator and eulogized on its

simplicity. Regarding the low pressure air system for tramways, this system promised considerable advantages over the high pressure system ; but he expressed doubts as to it being able to cope with the heavy traffic and high speeds necessary in working the Sydney traffic. He pointed out that the Sydney tramway system was really a system of street suburban railways. Referring to the traffic at the busy times of the day it was mentioned that it was an everyday occurrence to see a tram engine drawing two cars with as many as 200 passengers, and taking the approximate weight of the engine as 16 tons and the cars as 8 tons each, this gave a dead load of 32 tons, and taking Mr. Selfe's estimate as 15 passengers to the ton, the paying load would be $13\frac{1}{2}$ tons, or something like 30 per cent. of the total load, which showed that the rolling stock was not so unreasonably heavy as was supposed. When it was remembered that during the busy parts of the day with the present heavy system the trams followed at intervals of about one minute, and that each tram carried from 90 to 200 passengers, it was very difficult to see how trams with cars only capable of carrying 40 passengers could accommodate the traffic. He pointed out that the great difficulty with the Sydney trams was that the road was very much too light, and that the small stock of engines had been overworked, and that as a consequence heavy night repairs had to be carried out at a ruinous expense. The remark that it was impossible to work steam trams at a profit was an insult to engineers. With a good strong permanent way and a sufficiently large stock of engines to enable repairs to be done in the day time, there was no reason why the steam trams should not pay their way. He concluded with an expression of thanks to Mr. Selfe for the trouble he had taken in getting up his most valuable paper.

Mr. Selfe, in replying, said it was impossible at that late hour to deal with all the questions raised by the various speakers, or to take them systematically, but he would try to answer the principal points referred to. Several speakers, as the President and Mr. Poole, seemed to attribute the whole of the failure of the present system to the lightness and unsuitable nature of the permanent way, and he, Mr. Selfe, had seen much heavier lines (in one case with rails six inches deep), laid for horse cars, but one of these gentlemen admitted that the weight of an engine and two cars in Sydney was nearer 32 tons than the 24 tons put down for it in the paper, and claimed that for a short part of the day the average load was nearly 200 passengers. Nobody,

however, denied the statement of the paper that on many of the lines the average of the whole day was only about 20 passengers per train, and thus the arguments of the paper were really strengthened very materially if 32 tons of dead weight were to be taken to draw 20 passengers as the average work instead of 24 tons for 45 passengers, and in fact from the nature of things, such must be the case.* The Sydney tramways were principally employed in conveying passengers to and from the suburbs ; they were in fact suburban trains running through the streets, and did not do the work and earn the money by traffic through the crowded business streets of the city that tramways in most cities did. The author therefore held that it would be better to send five cars with 40 passengers each, instead of one train with 200 as at present, for the busy hours ; and let four of these cars lay up when not wanted, instead of running themselves and the road to destruction for no purpose, as the heavy tram trains do now, for the greater part of the day's work. It would probably be found that the first cost of five pneumatic cars would hardly exceed the locomotive and carriages to carry the same number, and it was certain the wear and tear would be so much less as to hardly admit of comparison. With regard to Mr. Cruickshank's fear that duplicate compressors would be necessary—of course spare and reserve compressing power would be provided, and perhaps on some streets liable to settlement, and where mains might be broken, it would be advisable to put double lines of pipes for extra security, but, at any rate, the percentage of reserve power would certainly be much less than with locomotive machinery, and as Mr. Cruickshank had just reported on stationary machinery at the Botany Waterworks, that had been in uninterrupted use for over 30 years, he was in a position to know what stationary engines and boilers could be expected to do. Mr. Mackay's idea that we wanted tram cars in Sydney very close to the ground, was met by two designs on the table, where the passengers sit back to back over the two long air cylinders, and the driver or conductor has a passage down the centre, in these cases the wheels are covered up, and the foot board was only a short distance above the ground. Mr. Henson's objection to the statement that

*It should be pointed out that there are several classes of motors working the Sydney traffic, and that on the branches where the traffic is light, the lines are worked by the lighter class of engines and a single car ; therefore the proportion of dead to live weight is not so great as would appear from Mr. Selfe's remarks.—Ed.

all the energy of compression is converted into heat is a common one, but although the author may not always have expressed himself in the clearest language, all his statements and tables were based on the highest authorities, nevertheless some clerical errors had crept into the proofs that would probably be set right before printing. The author did not go forth to seek this system, but it had been brought under his notice in such a way, and had so much to recommend it, that until he heard some sounder argument or more valid reasons put forth than had been used in the discussion, he should continue to think it well adapted for the wants of Sydney.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

TABLE A SHEWING THE RELATIVE QUANTITY OF WORK REQUIRED TO COMPRESS A GIVEN VOLUME AND WEIGHT OF AIR, BOTH DRY AND MOIST; ALSO RELATIVE VOLUMES WITH AND WITHOUT INCREASE OF TEMPERATURE FROM COMPRESSION.

From CORNET & MALLARD.

Tension in Atmospheres.	Compression at a Constant Temperature. Marriott's Law.			Compression with increase of Temperature.						Loss of Work in Compressing one Cubic Metre in Killogram-metres.	Per centage of Work of Compression converted into Heat and Lost.	Final Temperature if Water is used in Compression.	Per centage of Water to Air required.	Foot Pounds to compress 1lb. Air.	
	Volumn	Work of Compression.		Volumn	Work of Compression. (Dry.)		Temperatures. (Dry.)		Ratio of Greater to Less Temperature. Absolute.	By increase of Temperature alone.				Dry.	With sufficient Moisture.
		Cubic Metres in Killogram-metres.	Cubic Feet in Foot Pounds.		Cubic Metres in Killogram-metres.	Cubic Feet in Foot Pounds.	Centge.	Fah.							
			Deduced from 3.			Deduced from 6.						Fah.			
1	1						20	68	1.0			68			
2	.5	7199	1468	.612	7932	1618	85.5	186	1.222	733	.092	111	3.0	23500	22500
3	.333	11356	2316	.459	13360	2725	130.4	267	1.375	2004	.150	135.5	4.0	37000	35000
4	.25	14260	2909	.374	17737	3618	165.6	330	1.495	3477	.196	153.5	4.8	48500	45000
5	.200	16580	3383	.320	21209	4326	195.3	384	1.595	4629	.213	167.	5.4	58500	52500
6	.167	18475	3768	.281	24310	4959	220.5	429	1.681	5835	.240	179	6.0	67000	60000
7	.143	20038	4087	.252	27048	5517	243.2	470	1.758	7040	.260	190	6.4	75000	66000
8	.125	21422	4370	.229	29518	6021	263.6	506.5	1.828	8096	.274	...	...	.....	.....
9	.111	.....	.....	.210	.....	.....	282.	539.6	1.891	.....	....	.....	...	.....	.....
10	.100	.....	.....	.195	..	.....	299	570.2	1.950	.....	.....	.....	...	.....	....
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

TABLE B SHEWING THE RELATIVE EFFICIENCY OF COMPLETE EXPANSION AND FULL PRESSURES WITHOUT EXPANSION, ALSO INITIAL AND FINAL TEMPERATURES.

From M. MALLARD and D. K. CLARK

Ratio of Initial to Final Pressure.	Ratio of Final to Initial Absolute Temp.	Air admitted the whole stroke.				Air completely expanded.				Ratio of Efficiencies obtained from Full Pressures in Cylinders and Complete Expansion.	
		Temperatures Centigrade.	Temperatures Fahrenheit.	Theoretical Efficiency.	Theoretical Efficiency.	Temperatures Centigrade.	Temperatures Fahrenheit.	Theoretical Efficiency.	Theoretical Efficiency		
	Clark.	Mallard.	Clark.	Mallard.	Clark.	Mallard.	Clark.	Mallard.	Clark.	Mallard.	Clark.
				Expansion only.	Compression and Expansion.			Expansion.	Compression and Expansion.	Expansion.	Compression and Expansion.
1	1	20.c	62 Fah.			20 Cen.	62 Fah.				
2	.855	—22.4	—14	.82	.66	—33.4	—33	.855	.82	.95	.80
3	.806	—36.9	—40	.72	.52	—60	—81	.806	.73	.90	.71
4	.782	—43.2	—52	.67	.44	—77	—111	.782	.67	.86	.66
5	.768	—48.0	—60	.63	.39	—89	—133	.768	.63	.82	.62
6	.758	—51.0	...	.60	...	—98	...	.758	...	.79	...
7	.751	—53.0	...	.57	...	—106	...	.751	...	.74	...
8	.746	—54.5	...	.55	...	—112.7	...	.746	.	.73	...
9	.742	—55.6	...	.53	...	—118.1	...	.742	...	.71	...
10	.739	—56.5	—75	.51	.27.5	—122.9	—193	.739	.51	.69	.54
1	2	3	4	5	6	7	8	9	10	11	12

MINUTES OF PROCEEDINGS.

8th APRIL, 1 86.

Walter Shellshear, President, in the chair.

The following candidates were balloted for and duly elected as

MEMBERS:
W. M. NOAKES.
WM. PAISLEY.

Mr. WALTER SHELLSHEAR then read the following paper, the discussion on which was held at a special general meeting on the 29th April. During the reading and discussion of the paper, Mr. Trevor Jones, Member of Council, occupied the chair.

ON THE CONSTRUCTION OF BREAKWATERS AND TRAINING JETTIES.

WORKS for providing shelter to ships in time of storms, and for facilitating trade must at all times be of interest to a country whose chief source of wealth is to be found in commerce, and with our extended seaboard and rapidly developing trade, a paper on the subject of the construction of breakwaters and training jetties should be of some little public interest, and it is to be hoped that the discussion of this subject may be of practical utility.

It is proposed, firstly: To consider the different forms of breakwaters that have been constructed for the protection of bays and the formation of artificial harbours. Secondly: To describe the various forms of training jetties that have been used for the improvement of river entrances, with a view to showing how far the valuable experience gained in other parts of the world may be profited by in New South Wales when works of this class are taken in hand with the object of improving the shelter of our bays, and the removal of the sand bars from our river entrances.

The object to be attained by the construction of a breakwater is to provide shelter to ships in time of storms, and still water where the operation of loading and discharging cargo can be carried on without danger or inconvenience.

Before considering the various details of construction, it may be well to examine the forces that are brought into play by the waves.

If this part of the subject is carefully studied, the author is of opinion that the cause of many of the failures that engineering history records may be understood, and the inherent weakness that has proved to exist in these cases can be guarded against, and the chances of success to a great extent insured.

The following description of wave-motion in water is founded chiefly on the theoretical investigations of Mr. Airy (now Sir George B. Airy) and others, and the observations of the Messrs. Weber and of Mr. Scott Russell, with a few additions founded on later researches :—

Rolling waves in water are propagated horizontally, the motion of each particle takes place in a vertical plane, parallel to the direction of propagation ; the path or orbit described by each particle is approximately elliptic, and in water of uniform depth the longer axis of the elliptic orbit is horizontal, and the shorter vertical ; the centre of the orbit lies a little above the position that the particle occupies when the water is undisturbed ; when at the top of its orbit the particle moves forward as regards the direction of propagation, when at the bottom, backwards.

The particles at the surface of the water describe the largest orbits ; the extent of the motion, both horizontally and vertically, diminishes as the depth below the surface increases, but that of the vertical motion more rapidly than that of the horizontal motion, so that the deeper a particle is situated the more flattened is its orbit ; a particle in contact with the bottom moves backwards and forwards in a horizontal straight line.

In water that is deep, as compared with the length of a wave (or distance between two successive ridges on the surface of the water) the orbits of the particle are nearly circular, and the motion at great depths is insensible.

The period of a wave is the time occupied by each particle in making one revolution, and is also the time occupied by a wave in travelling a distance equal to its length. Thence we have the following proportion :—

$$\frac{\text{Mean speed of a particle}}{\text{Speed of the wave}} = \frac{\text{Circumference of particle's orbit.}}{\text{Length of wave.}}$$

The speed of the waves depends principally on their length and on the depth of water, being greatest for long waves and deep water.

When the depth of water is greater than the length of a wave, the speed is not sensibly affected by the depth, and is almost exactly equal to the velocity acquired by a body in falling through half of the radius of a circle whose circumference is the length of a wave. In water that is very shallow, compared with the length of the waves, the velocity is nearly equal to that acquired by a heavy body in falling through half the depth of the water added to three-fourths of the height of a wave.

Two or more different series of waves moving in the same, different, and contrary directions, with equal or unequal speeds, may traverse the same mass of water at the same time, and the motion of each particle of water will be the resultant of the respective motions which the several series of waves would have impressed upon it had they acted separately. This is called the interference of waves.

When a series of waves advances into water, gradually becoming shallower, their periods remain unchanged, but their speed, and consequently their length, diminishes, and their slopes become steeper. The orbits of the particles of water become distorted, as at B C D (Plate 10, fig. 1), in such a manner that the front of each wave gradually becomes steeper than the back; the crest, as it were, advancing faster than the trough. At length the front of the wave curls over beyond the vertical, its crest falls forward, and it breaks into surf on the beach.

As the energy of the motion of a given wave which advances into shallowing water, or up a narrowing inlet, is successively communicated to smaller and smaller masses of water, there is a tendency to throw these masses into more and more violent agitation; that tendency may either take effect, or it may be counteracted, or more than counteracted by the loss of energy which takes place through the production of eddies and surge at sudden changes of depth, and through friction on the bottom.

When waves roll straight against a vertical wall as in Plate 10, fig. 2, they are reflected, and the particles of water for a certain distance in front of the wall have motions compounded of those due to the direct and reflected waves. The results are of the following kind:—The particles in contact with the wall, as at A, move up and down through a height equal to double the height of the waves, and so also do those at half a wave length from the wall, as at C; the

particles at a quarter of a wave length from the wall, as at B, move backwards and forwards horizontally, and intermediate particles oscillate in lines inclined at various angles.

In order that a surface may reflect the waves, it is not essential that it should be exactly vertical. According to Mr. Scott Russell, it will do so even with a batter of 45 deg.

A vertical or steep surface which is wholly covered by the water, reflects the wave-motion of those layers of water which lie below its level, and thus a sunken rock or breakwater, even though covered with water to a considerable depth, causes the sea to break over it, and so diminishes the energy of the advancing waves.

The greatest length of waves in the ocean is estimated at about 500 feet, which corresponds to a speed of about 53 feet per second, and a period of 11 seconds. Their greatest height is given by Scoresby as about 43 feet, and this, with the period just stated, gives 12 feet per second as the velocity of revolution of the particles of water.

In smaller seas the waves are both lower and shorter, and less swift; and, according to Mr. Scott Russell, waves in an expanse of shallow water of nearly uniform depth never exceed in height the undisturbed depth of the water. But the concentration of energy upon small masses of water, which occurs on shelving coasts in the manner already stated, produces waves of heights greatly exceeding those which occur in water of uniform depth, as the following examples show. Pressures of waves against a vertical surface, at Skerryvore, as observed by Mr. Thomas Stevenson :—

	Summer average.	Winter average.	Storms.
In lbs. per square foot... ...	611	2086	6083
In feet of water...	9.8	33	97

Greatest height of breakers on the south-west coast of Ireland, as observed by the Earl of Dunraven, 150 feet.

Recent investigations tend towards the conclusion, which is in accordance with observation, that every wave is more or less a "wave of translation," setting down each particle of water, or of matter suspended in water, a little in advance of where it picked that particle up, and thus by degrees producing that heaping up of

waves which gather on a lee-shore during storm. This property of waves accounts for the facts that, although they tend to undermine and demolish steep cliffs, they heap up sand, gravel, shingle, or such materials as they are able to sweep along, upon every flat or sloping beach against which they directly roll, that they carry such materials into bays and estuaries, and that when they advance obliquely along the coast they make the materials of the beach travel along the coast in the same direction.

The action of waves against a vertical wall is well illustrated in the case of the new breakwater at Wicklow. The waves never strike this breakwater a blow; they rise strongly and pile up against the breakwater, the rebounding wave annihilating the incoming wave. The extent to which waves acting obliquely along a coast cause the materials of the beach to travel is well illustrated along the coast of New South Wales, where at almost every inlet sand spits are found forcing their way across the entrance by this action.

The effect of a wave rising up against a breakwater is to cause a considerable difference of pressure against the two sides of the wall, and if the wall is not solid, or founded on loose material, the hydraulic pressure due to the differences of height will cause the water to be forced through every joint with a great velocity, thus tending to wash out the materials from the foundation. Again, as the wave recedes the action will be reversed, and when it is remembered how great this difference of pressure may be in time of storms it is not difficult to imagine that considerable displacement may take place in the foundations when these are constructed of loose rubble, and that the various parts of the structure will sooner or later be ground to shingle by the motion imparted to them by undulations of the waves.

The consideration of the above action leads to the question of foundations and the security of this part of the work is of the first importance. The bottom at the site of a breakwater may be rock, clay, gravel, or sand, and it is evident that the plan of securing the foundations will have to be modified to suit the nature of the bottom. In describing the different types of breakwaters, the various plans for securing the foundations will be considered as they may be applicable to the class of work under discussion.

The range of tide is an important factor when considering the cost and strength of a breakwater, as the greater the range of tide the larger the surface of the works exposed to the maximum effect of the waves. With these few preliminary remarks it is next proposed to describe the various types of breakwaters protecting harbours in various parts of the world.

Breakwaters may be classed under three heads:—Firstly: Those constructed of loose blocks of stone or concrete, and deposited without regard to bond, the materials taking their natural slope under the action of the waves. This system is known as the *pierre perdu* (literally "stone at random") system. Secondly: Those constructed with a *pierre perdu* base up to near low water-mark surmounted by a solid superstructure of masonry or concrete. Thirdly: Those constructed with solid masonry or concrete throughout.

Of the first system of constructing breakwaters, namely: the *pierre perdu* or random block system, the breakwater at Plymouth (Plate 10, fig. 3), is a good example. It is formed in a bay sheltered on three sides by land rising to a considerable height, and only open to the south. Several banks or natural reefs of rock exist, between which and the shore there were three principal passes towards the east, the west, and in the centre. The breakwater is erected on the banks situated the nearest to the interior of the harbour, and closes the centre passage. The banks situated more towards the open sea serve to break the fury of the waves before they arrive upon the breakwater. The main body of the breakwater is placed perpendicularly to the south-south-east, from which quarter the severe storms assail the Plymouth roads. The total length is 1,700 yards, and the two arms, forming on either side angles of about 135 deg. with the centre, occupy respectively 350 yards each. A surface of about 1,120 acres is, by means of this work, rendered available for large vessels.

Originally it was intended to make the width of the top of the breakwater only 11 yards, and the bottom about 55 yards; but during the execution of the works the width of the top has been increased to 15 yards, and that of the bottom to 133 yards. At the level of the low water at spring tides a set-off 22 yards in width is formed, and the slopes from this point upwards, on the sea side, are

paved with large stones 4 feet by 3 feet 6 inches, by about 3 feet thick, laid with an inclination of 5 base to 1 height and bedded in Roman cement; and it is proposed to continue this paving below low water line by means of the diving-bell. The height of the crown is only 2 feet above the level of high spring tides.

It appears to be beyond question that the long slope of the Plymouth breakwater is less exposed to be injured by violent shocks of the sea than in the case of Alderney (to be hereinafter described) where a vertical wall surmounts the rubble mound; but at the same time it is equally beyond question that the latter destroys far more effectually the agitation and undulation of the open sea, and offers a greater resistance to their transmission into the inner harbour, because the waves in Plymouth Sound during violent storms break over the slope; whilst in the case of works built on the system adopted at Alderney all their effect is destroyed by the wall. In the latter case, however, the descending motion of the return wave is materially interfered with. The vertical wall at the top of the long slope transforms it, in fact, into a horizontal motion, whose velocity is highly dangerous to the stability of the foundation of the wall. It is also found that the large blocks of stone detached from the outer slopes are driven against the outer face of the wall with extraordinary violence during great storms, whilst upon the long paved slope of the Plymouth breakwater the waves not meeting with any abrupt resistance, break in precisely the same manner upon the incline that they would do upon a natural shore, and with a considerably diminished degree of violence. It is true that, in consequence of this form, they acquire an increased horizontal velocity in their original direction; but as the top of the slope is rendered as smooth as possible, there are no salient points in the masonry able to attract, as it were, the destructive action of the waves. Notwithstanding the precautions observed in the execution of the top slope of the breakwater, it is by no means of rare occurrence that blocks weighing from 2 to 5 tons are carried over from the sea to the land side; and in February, 1848, considerable damage was caused to the upper parts, showing that even with special precaution of paving the slope with large blocks set in cement, it is by no means uncommon for the mound to be considerably disturbed in time of storms. The cost of this work was very considerable, being no less than £300 per foot run. The average cross section of the breakwater is about 19,920 square feet.

The breakwater at Algiers is another example of this system of construction. This work was at first constructed wholly of large blocks of concrete, about 13 cubic yards in volume, weighing about 25 tons each, in water averaging 50 feet deep. But in prolonging the mole, since 1847, a less costly system was adopted according to Plate 10, fig. 4. Small rubble was deposited on the bottom, up to a level 33 feet below the water line, to the natural slope of 1 to 1, so economising, to a great extent, the cost for the sub-structure. Upon this base the remainder of the work, consisting of blocks of concrete, was deposited to a slope of $1\frac{1}{4}$ to 1 on the seaward side, and of 1 to 1 landwards, finishing at the water line at a width of 46 feet. The cost of the breakwater amounted to £122 per lineal foot. The average cross section of this breakwater is about 5,000 square feet.

But, comparing this with Plymouth, it must be remembered that there is practically no tide at Algiers and a range of about 15 feet at Plymouth. The principal disadvantages of the *pierre perdu* system are the great quantity of material required in their construction, and the liability of being gradually converted into banks of shingle by the continual motion of the various stones, of which they are constructed, grinding each other firstly from angular blocks to boulders, and then from boulders to shingle, and also the liability of considerable displacement of the material in time of storms.

Of the second system, namely: that with a rubble base deposited *pierre perdu*, and a solid superstructure, three examples may be briefly referred to. The first is the Alderney breakwator. This work was commenced in 1847 and completed in the end of 1864. The rise of spring tides is 17 feet, and the depth at low water increases from 45 feet near the shore to 133 feet at the head of the pier. The total length of the breakwater is 4,700 feet. On a long slope base of *pierre perdu*—hard stone from Manney quarry—large and small, the superstructure for the most part consists of a sea-wall and a harbour wall, with filling in the intermediate space, surmounted by a promenade. It was constructed with a few modifications of structure as the work advanced The last 2,000 feet were constructed to the section Plate 10, fig. 5, the final length of 66 feet constituting the head of the pier was somewhat stronger. It was presumed that the rubble stone would not be disturbed by waves at a greater depth than 12 feet below low water, and the foundations of

the superstructure were carried to that level. The quay is 20 feet wide, and the promenade is 14 feet wide, making together a width of 34 feet. The faces were built with a batter of 4 inches in 1 foot. The quay stood 6 feet above high-water level, and the promenade was 10 feet higher. Great disturbances were experienced in the rubble mound. It was found impossible, even with the large quantities deposited for renewing the foreshore, to maintain the level of the mound close to the sea-wall at the level of low water. The disturbance extends to a distance as much as 80 or 90 feet from the seaward wall, at the maximum depth of 20 feet. The great distance and depth of the disturbing action are attributable, no doubt, to the recoil of the waves from the wall, as each wave, during a storm, rises to a great height above the breakwater, then falls and rushes down the slope to the mound, opposing an overpowering resistance to everything in its course till it rebounds some height into the air on meeting the next wave, at a distance of about 70 or 80 feet from the wall. It was estimated that at least 25,000 tons of large stone would be required to be deposited each year in order to maintain the sea-slope of the mound, and prevent the superstructure from being undermined. Breaches were made in the superstructure at various points—mostly in the deeper water. The rubble was dashed against the seaward wall, and, no doubt, helped to open the breaches. The superstructure subsided unequally at different portions, longitudinally as well as transversely, and cracks and openings were formed in the interior; so that the action of the water entering these openings, in conjunction with the confined air, under the pressure of the waves, aided in producing cracks. That subsidence, in a considerable degree, should have taken place under the weight of the superstructure on such an unprecedentedly deep base of rubble might have been expected. The settlement amounted to about one-twentieth of the height of the mound, though it was not uniform. At the head the superstructure settled at least six feet. The nature of the settlement is illustrated by the Plate 10, fig. 6. The total cost of the works of construction and maintenance, extending over a period of twenty-five years, amounted to £1,274,200. Of this sum £57,200 was expended in repairs of damages caused by the sea to finished and unfinished work, leaving the net cost, £1,217,000, at the rate of £259 per lineal foot, for a depth averaging probably about 90 feet below low water. The average cross section of the breakwater is about 13,000 square feet.

Another instructive example of the characteristic behaviour of mixed rubble foundations of breakwaters at the surface of the sea is supplied in the case of the breakwater at Holyhead Harbour. This breakwater consists, like that of Alderney, of a mound of mixed rubble quartz-rock from an adjoining hill, upon which is erected a substantial stone superstructure, finished with a transverse head carrying a lighthouse. The breakwater, 7,860 feet in length, in a depth of water averaging 40 feet at low spring tides, with a maximum depth of 55 feet. Ordinary spring tides rise 17 feet equinoctial tides, 20 feet. The slope of the foreshore, according to the section Plate 10, fig. 7, is 12 to 1 above low water, and for a foot or two below it, where it assumes a slope of 5 to 1, to a depth of 10 or 12 feet below low water, and thence about 2 to 1 to the bottom. Landwards the slope is $1\frac{1}{4}$ to 1. The width of the mound at low water level is at least 250 feet. In 50 feet of water the width at the bottom is about 450 feet. The weight of the rubble stone in bulk is 1 ton per 20 cubic feet. The stone was deposited from a temporary wooden stage.

The rubble mound having been formed and consolidated by the action of the sea, the superstructure was erected, for the foundation of which the rubble was excavated to the level of low water. The principal object of the superstructure was to shelter the interior of the harbour, and to prevent the loose deposit from washing into the harbour. The outer wall has a total thickness of $17\frac{1}{4}$ feet at the upper part, with a batter to the base, which is 23 feet wide. The total height to the top of the parapet is $25\frac{1}{2}$ feet above high water. The inner wall, distinct from the outer wall, is formed with a vertical face to the harbour and is 8 feet wide at the base. It stands 10 feet above high-water level. The width of the quay-way is 40 feet, and the total width at the base of the superstructure is 64 feet. The hearting consists of rubble. The total cost of the breakwater was £163 per lineal foot.

The rubble on the seaward side is exposed to the force of the waves at all times of the tide, and it is stated that it is subject to shifting and drifting, and to be reduced to the condition of shingle. From the ascertained results of the action of the sea at Alderney, this effect is what might have been expected. The flatness of the exterior slope, 12 to 1, is no doubt much below the angle of settlement of rubble under the action of the sea waves; and this

consideration may have formed an element in the original design in the anticipation that therefore the rubble would not be disturbed. It is on record, nevertheless, that as a matter of fact the rubble foreshore has been in some places washed away from the lower part of the superstructure, and in other places piled up to within a few feet of the parapet.

The breakwater at Marseilles (Plate 11, fig. 8) has been constructed upon a system embodying the combined experience of Cherbourg and Algiers. On the one hand, the idea of directly opposing the powerful action of the waves by enormous blocks, artificially constructed, has been taken from the mole at Algiers; while on the other the breakwater at Cherbourg suggested the employment of natural blocks of all dimensions to constitute the main body of the work. The former serve as a facing to the latter, and in the present instance both have been used simultaneously in such a manner as not to have the natural blocks exposed to the great force of the waves. As this force sensibly diminishes at a depth of about 15 feet below ebb-tides, the use of artificial blocks has been limited to about 20 feet below that level.

The value of large artificial blocks to protect the outer slope will be better understood when it is remembered that the action of the wave is in proportion to the surface struck, while the resistance of a block increases as its cube.

With the twofold view of solidity and economy, positions have been assigned to the natural blocks according to their respective dimensions. This course has been adopted in preference to the plan followed in the construction of the works already mentioned, in which the stone was used indiscriminately as it came from the quarry. From considerations of economy the small materials have not been mixed with the large in order to preserve the greatest possible void. With a view to solidity, the large blocks have been so disposed as to entirely surround the small ones.

Experience has fully confirmed the rationale of these ideas. The part of the breakwater which protects the basin of La Joliette was commenced 27 years ago, and is at the present time in an excellent state of preservation, time having, therefore, satisfactorily demonstrated the excellence of this system. The cost of this

work was very moderate, being only £122 per lineal foot; the depth of water being 35 feet, and the average cross section 5400 square feet.

Of the three examples given above, the work at Marseilles is undoubtedly the best, the careful arrangement of the materials, combined with the large concrete blocks, has effectually prevented the disturbance of the foreshore, so marked in the case of Alderney and Holyhead. Although, at the same time, it must be remembered that the tide at Marseilles is all but imperceptible, and the works are therefore not subjected to the maximum effect of the waves to the same extent as in the other cases, where there is a large range of tide.

Before describing the system of construction for breakwaters that has been pronounced by the English Select Committee on Harbour Accommodation as the best system of construction for breakwaters, it is proposed to describe two works that stand pre-eminent among engineering failures, and to point out what appears to be the lesson to be learned from this dearly bought experience. The Wick breakwater (Plate 11, fig. 9) was commenced in 1863. The outer exposed part of the breakwater was founded on a rubble mound at a level of 18 feet below low water of spring tides, and was carried up to the level of 11 feet above high water where it was 43 feet in breadth. In a severe storm in February, 1870, this work was greatly damaged, and it has since been all but completely demolished by the action of the waves. It is recorded that in 1872 a huge monolithic block of concrete, weighing in all 1,350 tons, was moved bodily out of its position and carried to the lee of the breakwater, and in 1873 a block of 2600 tons was similarly displaced. Wick is, no doubt, a very exposed bay, and this failure has been attributed to the abnormal force of the waves moving these large blocks bodily out of place, but after a very careful study of the history of this failure, the author thinks the balance of evidence goes to prove that the initial cause of this failure was the unequal settlement and displacement of the rubble base under the action of the exceptioually heavy waves, causing the superstructure to take a list to leeward, and subsequently to slide off the foundation course. The experience at Alderney gives strong evidence that the tendency of the waves is to cause the rubble base to settle unevenly in the way above described, and as there was no bond between the upper

part of the work and the foundation course of concrete blocks, it is not difficult to imagine that in the event of unequal settlement the force of the waves, assisted by the force of gravity on the inclined plane, would be more than enough to slide the superstructure off the foundation course.

The second case is the harbour of Madras. It was proposed to construct a large artificial harbour on the coast of Madras. The breakwaters were constructed of a double row of concrete blocks (each block weighing about 27 tons) founded on a rubble base, at a depth of 22 feet below low water (Plate 11, fig. 10.) This work was all but completed when a violent cyclone in November, 1881, disturbed the foundation mound 22 feet below low water, and scooped out the materials, a large portion of the work being thus destroyed. This partial destruction of the works is attributed to the above settlement of the rubble mound and the imperfect bonding of the concrete blocks.

It is recorded that laterite rubble, 150 lbs. per cubic foot, in blocks varying trom 5 lbs. to 2 cwt., composing the mound at Madras were removed at depths exceeding 40 feet by the cyclonic ground swell.

These examples show that when breakwaters are constructed on rapidly shelving coasts the action of the waves extends to a much greater depth than was formerly supposed. In the case of Wick the depth of water rapidly increases seaward, and the bay is of a V shape, thus giving every facility for an undulating wave to be converted into one of translation as it approaches the shore. The coast at Madras also shelves very rapidly, thus affording a similar opportunity for the nature of the waves to be changed, and it seems not at all improbable that in times of great storms the whole body of water under such circumstances would be more or less in motion, thus greatly increasing the destructive force on a rubble base.

These works were designed by engineers of great eminence and experience, and in referring to these failures it is simply with the object of pointing out the lesson to be learned from their experience, for, if there is one branch of engineering more than another where the works of others require careful study in order to make the best use of past experience, it is in the construction of sea works, and there is often more to be learned from a careful study of a failure than from the record of many successes.

The consideration of the construction of breakwaters built up solid from the bottom of the sea will conclude this part of the subject. Speaking of this system the Select Committee of the House of Commons, reporting on Harbour Accommodation, expresses the following opinion:—"Your committee have examined many eminent engineers, and have been much impressed with the practical unanimity of opinion expressed by them that the best system of construction for piers and breakwaters is to be found in building them up in solid monolithic walls of concrete. Different engineers have different methods of effecting this object, but whether, as at Newhaven, the system is adopted of sinking the concrete in bags, or whether, as recommended by Mr. Rendel, by means of caissons, or whether building it up without such assistance round a staging, as adopted by Mr. Strype at Wicklow, or whether by the system adopted by Mr. Dyce Cay, at Aberdeen, they are unanimous in declaring that the new system is far preferable to the older system of rubble or *pierre perdu* foundation."

The special advantage of a solid vertical wall over a long slope for a breakwater is, that on the long slope system, waves of oscillation are converted into ones of translation as they advance up the slope; whereas, with a vertical wall, they simply expend their force by rising up against the wall, and are deflected on to the waves approaching the works, as explained in the early part of the paper. The amount of material in a vertical breakwater is very much less than in a long slope breakwater.

Before Portland cement had been brought to its present high quality, and thus affording a cheap material by which reliable concrete could be manufactured, the difficulties of constructing a breakwater on the vertical system were very great. The cost of dressing and setting large stones rendered this system all but impracticable on account of the great cost.

The pier at Dover is an example of this system, it being constructed with nearly upright sides from the bottom (Plate 11, fig. 11.) The choice of this form was, it is said, induced by the want of suitable stone in the district necessitating the carriage of stone from a long distance. The material below low water was put in place with the aid of diving apparatus, and the work was, of course, expensive, costing £290 per lineal foot for the first contract of 00

lineal feet, and for the second contract let in 1854, £415 per lineal foot. It is constructed with granite facings and a breasting of rectangular blocks of Portland cement and shingle concrete up to a little above half-tide level; above this the filling consisted of liquid concrete. The pier, though at present it is essentially a landing pier, is intended ultimately to be extended so as to form a harbour of refuge. It is formed with a uniform batter on each side, and is in section about 80 feet wide at the base, and 42 feet at the top, comprising a roadway 30 feet wide, and a heavy parapet on the seaward side. It is founded 45 feet below low water mark.

Another example of the vertical system is the breakwater enclosing the harbour at the entrance to the Amsterdam ship canal. This work is of special interest on account of the treacherous nature of the foundations.

The north and south breakwaters enclosing the harbour are each nearly 1550 métres (1695 yards), or together nearly two miles long. They shelter an area of about 250 acres, through the centre of which a channel 225 métres (738 feet) wide has been dredged. At the landward end this channel has at its junction with the canal a guide pier on each side, the northernmost being called the North Mole, and the southernmost the South Mole, each being 335 métres (366 yards) long.

The north and south breakwaters are similar in design (Plate 11 fig. 12). They were built on a very unfavorable foundation, consisting of very fine sand.

It was attempted in the first place to construct them by a staging of screw piles, but a slight disturbance of the sea excavated a hole round the piles, laying them bare or sufficiently so to destroy the staging. This plan was abandoned, and it was then tried, after partially excavating the sand, to set the concrete blocks by an overhanging travelling crane, which was to advance on the pier as the work was brought up. It was hoped that when the bottom blocks had been set they would, notwithstanding the disturbance of the sand, form a bed which could be levelled, and upon which the structure could be raised. This mode of procedure did not answer. It was then determined to substitute for the bottom course a layer of loose material consisting for the most part of basalt from the Drachenfels, and limestone from Belgium, thrown in as random work.

This was the plan finally adopted to secure a foundation. The mound of stone was deposited about 1 mètre ($3\frac{1}{4}$ feet) thick, and to a width about three times that of the pier at the base, so that when, by the disturbance of the sea, a trench was excavated at the sides of the mound, as was always the case, the loose deposit fell into the hollow until the normal slope was attained, leaving a central portion upon which to build the pier. By this plan when the piers advanced, the trench, which in places had been no less than 14 or 15 feet deep, gradually filled up. The stones of the deposit varied in size from about one cubic foot and under. In levelling the deposit for the reception of the first course of block work, the interstices were filled with hard broken bricks, big shingle, or stone broken to sizes of about 3 inches square. When possible the deposit was exposed for twelve months to the action of the sea before being built upon, by which time the surface became covered with mussels, and was very hard, so that it was difficult to disturb it by iron bars or otherwise.

The concrete blocks of which the chief portion of the solid structure of the piers is composed varied in weight from 6 tons to 12 tons, and were made of one measure of Portland cement, three measures of coarse river sand, and five measures of shingle, the sand being obtained from the Rhine at Vreeswijk, and the shingle being dredged from the Rhine chiefly in the neighbourhood of Nymegan.

The concrete blocks were put in place for the most part by powerful overhanging travelling cranes, there being one such crane or "Titan" to each breakwater. Several designs of "Titan" were tried, which generally answered very well, but the north breakwater being more exposed, it was decided after the works had been considerably advanced and two "Titans" had been swept away, to employ a steam travelling crane, which was run out to its work by a locomotive engine, and brought back every evening for security in case of storms.

The rubble deposit was levelled and the blocks under water laid by divers. Laying the blocks was much facilitated by the use of a self-disengaging apparatus designed by Mr. Hutton. Below low water the blocks were set dry, but above low water they were set in Portland cement mortar, and were well clamped together. The upper portion of the structure was formed of concrete *en masse*.

The pier heads are square with rounded corners, and are 1 mètre ($3\frac{1}{4}$ feet) higher than the adjoining length of pier, which slopes up to the head with a gradient of 1 in 100. The heads are in line with the piers on the seaward side, but on the harbour side they have a projection of six feet.

The concrete mixers were designed by the contractors, and answered perfectly. Similar mixers had before been used by Messrs. Lee in the construction of the Admiralty Pier at Dover. When the piers were originally designed, the information supplied as to the rise of the tides was inaccurate, the tidal range being at times much greater than was then assumed. Partly in consequence of this the design proved too near the margin of safety for a sea work, and when the breakwaters were considerably advanced seawards, the wave breaker on the sea side was added, The extent of the wave breaker on each breakwater was determined by the degree of exposure. It begins about 100 métres (328 feet) nearer the coast line on the north breakwater than on the south breakwater, on account of the former being exposed to seas somewhat heavier than the latter. Gales of wind affecting the breakwater being from the south-west and strike upon the south breakwater, and almost invariably end from the north-west, striking on the north breakwater, the latter part of the gale being generally more destructive than the former.

The wave-breaker consists of concrete blocks deposited *perdu*; the weight of the lower blocks is about 10 tons, and of the upper blocks 20 tons These blocks are disturbed by the sea until they form a slope of about $1\frac{1}{2}$ to 1. The cost of these breakwaters, including the wave breaker was about £107 per foot forward.

The south breakwater at Aberdeen is another example of this system. It is 1050 feet in length, in a depth of water of 22 feet 3 inches at the head, low water spring tide. The total height at the head is 40 feet, and the breakwater stands 11 feet above high water, with a rise of tide of 12 feet 9 inches. At the shore end the width at the top is 30 feet, and (Plate 11, fig. 13) near the outer end it is 35 feet; the batter at the sides is $1\frac{1}{2}$ inches to 1 foot. The foundations rest on granite rock, on boulders and gravel, and on clay mixed with gravel. Upon the ground which was cleared of loose stones and sand, a layer of bags of concrete was deposited. The bags of concrete, each holding five tons, were lowered in wrought iron skips, the

bottoms of which were on hinges, and were opened to let the bags fall when they were into position. Each bag was flattened out, and when it stood too high it was beaten down; or if partially set, cut down. Small holes in the surface were filled with bags deposited by hand. The proportions of the concrete were, 1 of cement, $2\frac{1}{2}$ of sand, and $3\frac{1}{2}$ of gravel.

For a length of 393 feet, extending to low water, and to the edge of the rocky foreshore, the breakwater was built of liquid concrete deposited in place in frames or cases. The upper portion of the breakwater, from a depth of 18 feet, was likewise constructed of liquid concrete to the head of the breakwater. Each piece of concrete, as laid, extended completely across the breakwater, and the lengths of pieces were from 8 feet to 31 feet, making pieces weighing from 305 to 1300 tons. In the construction of the larger pieces, blocks of concrete were thrown into the mass. The concrete was composed of 4 of sand, and 5 of gravel, to 1 of cement.

From the bag work in the foundations up to 1 foot above low water of neap tides, where the liquid concrete work just described was commenced, the work was composed of blocks of concrete 4 feet high and usually 6 feet wide, weighing from $10\frac{1}{2}$ tons to 24 tons. The composition of these blocks was the same as that of the concrete just described. Large rough pieces of broken stone were incorporated.

An apron of concrete was placed along the seaward side of the foundations, consisting of 15 bags of concrete, containing 100 tons each, to obviate the chance of damage from undermining by the sea.

The work was commenced in 1869, and completed, with a lighthouse, in 1873. The net total cost, including the charge for plant and sea-staging, amounted to £68,000, being at the rate of £65 per lineal foot.

This work illustrates the great advantage to be gained by the use of concrete, both as regards the time taken to construct the works and their cost, which, considering the amount of bad weather on this part of the coast, and the substantial nature of the work, must be considered very moderate.

In the above examples of the vertical system the method of construction has involved the use of expensive cranes, and the constructures can hardly be considered monolithic as the separate blocks

below water being set dry are therefore depending upon their own weight, and the superincumbent weight of the upper part of the structure for their stability, and to a certain extent the joints may be looked upon as lines of weakness.

A description will now be given of some of the most recent examples of the monolithic system, and its special advantages pointed out.

The small fishing harbour of Buckie on the East Coast of Scotland has recently been protected by a breakwater built on a very exposed site on a rocky bottom. This breakwater is a very good example of a monolithic breakwater ; it is constructed throughout of Portland cement concrete built in *situ*, the material being deposited between timber framework planked inside, made and erected to suit the various sections of the work. The planking was lined inside with several thicknesses of jute cloth, to prevent the cement being washed out. Although the timber was of great strength it was on several occasions washed down by the sea during the progress of the work, but in spite of these mishaps the work was successfully completed at a moderate cost, the amount spent on plant being very small. The rise and fall of tide at Buckie is about 11 feet.

The breakwater at Newhaven now being carried out under Mr. F. D. Banister, M. Inst., C.E., and in accordance with his plans, is constructed of Portland cement concrete, on a system that was carried out to a minor degree at Aberdeen, but which has been very successfully carried out at Newhaven, at a comparatively very low cost.

The foundation is formed by sinking bags of soft concrete, weighing 100 tons each, from a steam hopper barge which is put under a concrete mixing machine in the interior of the harbour, and in the space of 20 minutes the 100 ton bag is filled. The men on board immediately sew up the top of the bag while the barge is passing from the inner harbour to the side of the breakwater. It then steams slowly across the line of the breakwater, and at a given moment a man lining it on the centre of the breakwater gives the signal, the hopper is struck, and the bag descends into its place. The system goes on constantly, and the material being in a soft state accommodates itself to the concrete already set at the bottom, and forms one homogenous mass. The work is thus brought up to low-

water mark. The bags are found to bind together in one complete mass and form a solid rock. When the bags have been deposited, and the work brought up to about one foot above low water mark so that the men can just work upon them without being washed, the surface is formed and a framing erected for the superstructure, the frame is lined with timber work, and the concrete mixing machine is taken along the breakwater very nearly to its extremity and tips the concrete into waggons which run down to the framing and shoot in the material between the frames, the work is thus brought up to a height of ten feet above high-water mark.

The breakwater is forty-two feet wide at the bottom and thirty-two feet at the top. The depth of water is from 15 to 16 feet at low tide, and the work is to be extended out to a depth of 18 feet. The rise and fall of the tide at Newhaven is 20 feet spring and 15 feet neap tides.

The cost of the concrete, including plant, averaged 15s. per cubic yard in place. The proportion of the concrete are one of Portland cement, five parts of shingle and two of sand.

The 100-ton bags of concrete are 42 feet long; each bag therefore being the full width of the breakwater. The bags are made of jute cloth, and are double thickness at the bottom.

The average cross section of the breakwater is 1840 square feet, and the cost of the work has averaged £57 per foot forward.

The nature of the bottom is sand on clay and chalk, the surface of the clay and chalk is overlaid by about two feet of sand.

The breakwater at Wicklow (Plate 12. fig. 14) recently constructed under the harbour engineer, Mr. William George Strype, Assoc. M. Inst., C.E., is a work of great interest on account of the novel system upon which it has been carried out, and its small cost.

The breakwater has a total length of 750 feet. The depth of water at low water spring tide is 18 feet at the head. The rise and fall of the tide is about 9 feet. This work took about $2\frac{1}{2}$ years to construct. The following is the plan upon which this work was carried out:—A central stage was first formed on which the engines, the waggons and the cranes ran. The stage was extended in advance of the work to about half the length of the breakwater, and the staging trestles secured by means of a pad of concrete, which is shown

upon Plate 12, fig. 14. (1). A pad of about 70 or 80 tons of concrete being deposited, the trestles thus secured are carried (as will be seen by the elevation) a long distance in advance of the general progress of the work. As soon as the staging was secured by this means a large mound of concrete was deposited as shown in Plate 12, fig. 14 (2); this mound of concrete representing about two-thirds of the volume of the solid structure below low water. This mound steadied the staging very considerably, and also admitted of very rapid progress in the construction of the work. During the construction of the mound as much as 2000 tons of concrete were deposited in a week, and for a small work that is considered a very remarkable pace at which to lay concrete. Upon the mound an outside deposit of concrete was added to the form of the breakwater, as shown by Plate 12, fig. 14 (3), by means of a panel rendered heavy so as to make it sink. This deposit was raised to within three feet of low water line. The difficulty of this system of construction is more when you get near to the level of low water. At low water the disturbing waves are apt to wash the cement out of the concrete before it is set. By putting the first stretch of panel within three feet of low water, the first profile toe can be deposited or formed as shown in the figure. As soon as that sets, which it does in a day or two, a second panel is placed in position, as shown in Plate 12, fig. 14 (4), and the profile of the work is carried up above the level of high water. For this part of the work it is necessary to select very calm water so as to avoid disturbance of the work; this being the most trying part of the work. While the structure is being formed, as shown in Plate 12, fig. 14 (4), the inside is carried up to the height of low water as shown in Plate 12, fig. 14 (5) the work being over low water mark is quite easy. Plate 12, fig. 14 (6) shows the building of the superstructure which can be readily accomplished.

The concrete used at Wicklow was made of gravel and sand obtained by dredging, the material being remarkably good; the proportion of cement to gravel and sand was one of cement to six of gravel and sand for the face, and one of cement to seven of gravel and sand for the inside of the work. The concrete for the submerged portion of the work was mixed dry, and left to find its own water on submersion.

The volume of the breakwater is about 40 cubic yards per foot run, and the cost of the work is about 17s. 3d. per cubic yard; the works therefore costing under £40 per foot run. The breakwater is built on a marl bottom.

The system adopted at Wicklow, and by which the breakwater was successfully carried out, possesses several points of peculiar interest. Firstly: compared with most other works of its class, the appliances used were of the simplest and cheapest description; no heavy cranes or special barges being required; secondly, in the event of a storm during the progress of the work, the mischief done would be simply confined to washing away the unset concrete which could be replaced without difficulty. There seems good reason to believe that where works are carried out on this system the amount of loss resulting from the washing away of the unset concrete, even in an exposed position, would be a less serious item than the cost of the heavy plant required for setting large blocks or depositing bags of large capacity, and with care and judgment on the part of those entrusted with the work, the loss could be reduced to a minimum, and a good rate of progress secured.

From a study of the above imperfect history of the progress that has been made in the science of constructing breakwaters, with a view to the arrival of a sound conclusion as to the best method of carrying out works of this class on the coast of New South Wales, the author is of opinion that there can be little question as to the advantage of the monolithic system, both as regards economy in first cost, and freedom from disturbance after completion; as, even in the case of a sandy bottom, works on this principle can be successfully carried out if similar precautions are taken to those found necessary in the breakwaters at the entrance to the Amsterdam canal.

It must also be remembered that, with the small range of tide along our coast, the difficulties of construction would be reduced, and for a given low-water depth the bulk of material required would be much less than in the case of most of the works referred to, where the range of tide varies from 10 to 20 feet, as against our tidal range of from 3 to 5 feet.

Again, comparing the average number of days, when the sea is sufficiently calm to enable works of this class to be carried on, it must be admitted that New South Wales is by no means unfavourably placed.

The second part of the subject, namely, the construction of training jetties will now be considered.

There are few countries in the world where the necessity of works of this class are more urgently required than in New South Wales. Our coast rivers being the natural outlet for the trade of our splendid coast districts, and these rivers being all more or less obstructed by dangerous sand bars, the question of the construction of training jetties to remove these obstructions must be one of the first importance. The author has already dealt at considerable length in other papers with the question of the best lines for works of this class, and in this paper the question of the economical construction of training jetties will alone be considered.

The objects to be attained by the construction of training jetties are to confine the inlet and exit of tidal and upland waters within definite limits, and to obstruct the progress of sand as it tends to force its way across the entrance of a river by the action of the waves. Unless it is essential, from local circumstances, that there should be still water immediately within the works (in which case breakwaters would have to be substituted for simple training jetties), there is no necessity for training jetties to be carried up to the height required in the case of breakwaters.

The rapid changes that take place in the position of the channels of all bar bound rivers. make it essential on the ground of economy that works of this class should be carried out with the greatest despatch, so that they will be affected as little as possible by such local changes. Moreover, the works themselves bring about considerable changes as they are pushed forward; thus, in the early stage, part of the works near the shore line may be exposed to the waves to a considerable extent, but as the works progress this part of the jetty may be completely protected by the growth of the beach along the jetty. It, therefore, follows that if the works are pushed forward with despatch, the part near the shore line can be constructed on a much less costly plan than would be the case if the works were only carried out at a slow rate of speed.

Within the last few years the Americans have made great advances in the science of constructing training jetties, as along their extended seaboard they have many rivers obstructed by shifting sand bars, under circumstances much less favourable for successful

treatment than is the case with the rivers on our coast; for, although the rise and fall of the tide is about the same, the distance to which the shallow water extends is much greater on the coast of America than it is with us. Thus, at Charleston, where important works are under construction, a depth of 20 feet is not reached until the jetties have been carried out a distance of something like three miles from the shore; whereas, in the case of most of our rivers, that depth is reached within 2000 feet.

In carrying out works of this class on shifting sand, it is essential to economy that the bottom should be protected for some distance in advance of the raised portion of the works, for otherwise the current round the ends of the advancing works will scour out the sand, thus making large pits which continually grow out as the works proceed, and require vast quantities of material to be deposited to make up for the sand that has been washed away. Again, it is not necessary in order to attain the object in view, namely, to secure a permanent fixed channel, that the works should be carried up above half tidal mark, for with works at that level the best effect of the latter half of the ebb tide, and the scour from the upland waters, is retained, and the sand is prevented from pushing across the entrance; at the same time the crest of the waves pass over the works, and they are not, therefore, subjected to the action of the recoil which, as pointed out in the early part of this paper, is the most destructive agent that is brought into play in the case of works carried up to a higher level.

The works for improving the entrance to Charleston Harbour were begun in 1879. They consist of a north and south jetty; the north jetty is 8,840 feet, and the south jetty 13,040 feet long. They consist of a superstructure of reprap stones, with rather low side slopes resting on a mattress of logs covered with fascines. Plate 13, Fig. 15, shows the plan of constructing the log mattresses. Their sea-ends, for a length of 3,000 feet on the north jetty, and 3,500 feet on the south jetty, have their crests at the level of half-flood of spring tides, or three feet above mean low water. The slope on the exterior faces of the jetties will be 1 upon 2 throughout their entire length. On the interior faces it will be 1 upon $1\frac{1}{2}$, except on the sea-ends, where, for a distance of about half-a-mile, it will be 1 upon 2. For the north jetty, the minimum width on the top is 15 feet at the lowest

portion. The width increases outward to 24 feet, which is adopted for that portion which rises above mean low water mark. The south jetty has a minimum width of crest of 12 feet where it crosses the main channel, at a depth varying from 10 to 12 feet below mean low water. Thence outward the width increases to 24 feet for the highest part, as in the case of the north jetty. The plan of carrying out these works is as follows :—The log mattresses were floated out in long lengths, and sunk in position by depositing stones evenly over them, the foundation mattresses being carried out for their full length before the stone superstructure was raised upon them. After the completion of the foundation, the stone was gradually deposited and the jetties raised to their required height. According to the last reports these jetties had not been brought up to the full height, but they had already effected considerable improvements in the channel, the improvements in the channel progressing as the jetties are raised, and the tidal scour concentrated; and there is every probability of the estimated depth being fully realised.

By the use of log mattresses a good foundation is provided for the stonework, without which the quantity of stone would have to be greatly increased, the mattresses preventing the displacement of the sand by the local currents and eddies which are produced when stones of any size are simply deposited upon sand, at the same time they are sufficiently flexible to adjust themselves to the undulations of the bottom.

By the time the timber has been destroyed by the action of sea-worms, the stonework will be consolidated by the growth of coral and shells, and will in itself prevent the displacement of the sand.

Experience in Charleston Harbour, and on the shores of Holland, especially at the mouth of the Maas, bears testimony to the rapid growth of mollusca upon loose stones immersed in the sea near the outlets of fresh water tributaries, and to their effective use in cementing them, as it were, into one mass.

With low level works the sand washed over the submerged portion in time of storms will be carried out by the well directed ebb current produced by the works, and by keeping the crest of the works at as low a level as possible consistent with retaining a proper velocity in the channel, the destructive effect of the waves is reduced to a minimum.

There are many other works now in progress on the American coast, including the great works at the mouth of the Mississippi, where a depth of about 40 feet was secured, against a former depth of only 8 or 9 feet. The works at Galveston, the St. John's River, Florida, the Aransas Pass, Texas, and many others, all the training jetties for which are constructed similar to those at Charleston, the works being carried up to only about half-tidal level, and in some parts wholly submerged, the construction of the jetties varying in some cases where stone has to be brought from a distance. Fascine mattresses are largely introduced to economise the stone as much as possible, the plan being to lay a foundation course of fascine mattresses and then a layer of stone upon which a second course of mattresses is placed, succeeded by a second layer of stone and so on until the jetties have been raised to the required height. Suitable materials for the construction of fascines are abundant near the entrances of most of the American rivers.

The American system of construction could no doubt be applied with advantage in treating the rivers of New South Wales, although there might be some difficulty in the manufacture of the fascines as there is not the same abundance of suitable material available.

Another system of constructing works of this class, and one that is most eminently suitable for the successful treatment of our rivers, is the most ingenious plan adopted in the case of the now famous works at the Sulina mouth of the Danube. These works are among the most economical and successful works that have ever been carried out, and having stood the test of nearly thirty years contest with the elements, a somewhat lengthy account of their construction, maintenance, and consolidation should be of especial interest. The construction of these works is thus described by Sir Charles A. Hartley, under whose direction the works were carried out. "Several plans had been proposed for carrying out these works, and choice was finally made of a structure composed of piling and *pierre perdu*, surmounted by a timber platform 14 feet wide, strengthened occasionally by solidly constructed cribs of the same width (Plate 13, fig. 16). The works were commenced on the 21st April, 1858, and an account will now be given of the system of execution. A temporary staging fixed on piles, driven by ringing engines worked from barges, was run out from 200 feet to 300 feet in advance of the permanent piling

and although during the progress of the work it was several times partially destroyed by the violence of heavy gales, the repairs were easily and rapidly effected during fine weather. This staging supported nine crab engines, and working a monkey weighing 15 cwt., and driving down daily, on an average, a pile, 13 inches square, 16 feet into the hard fine sand of which the bottom is composed. By these means three rows of three piles each, at equal distances apart of 7 feet, were frequently driven in one day. They were then immediately secured by double longitudinal walings 12 inches by 6 inches, and double cross-ties 12 inches by 4 inches, and 15 feet long the whole being surmounted by two tram pieces 6 inches thick, and planking 3 inches in thickness, at 4 feet above the level of the sea. From this permanent platform the close piling on the side next the sea was driven by six similar crab engines, following closely on the open 7-feet bays in advance. The daily rate of progress during fine weather was 20 feet, and no sooner had this length of sheet piles been placed than stones were thrown down to protect its footing in the sand, which without such protection was liable to be washed away to such an extent by the beat of the sea as to endanger the stability of the exposed close piling, although driven 14 feet into the ground. The scouring action of the sea was the only real difficulty to contend against, and so serious did it become when the skirt of the bar was reached, along the line of open piling immediately beyond the sheeting, that although confined to that locality it threatened at one time to demand for the completion of the work double the quantity of stone originally estimated. . . . . To overcome this difficulty the following plan was adopted for a length of about 400 feet. Long rafts of unsquared timber ladened with fascines and stones were sunk between the exterior open piles as well on the river as on the sea side, so as to cover the base of the embankment by a layer of about 4 feet in thickness. This arrangement was economical but was too slow in execution. . . . . Recourse was then had to a plan which answered well in every respect, and by means of which the works were completed within the original estimate, and in less time than at first specified. The open pilework was advanced with all possible expedition, and the proposed seat of the advancing pier was paved with stones delivered from barges. This pavement withstood the attack of the sea, and offered no great obstruction to the pene-

tration of the sheet piles, which, without being shod, were frequently driven 10 feet into the ground after having been forced through 8 feet of rubble stones. In throwing down the stones from the barges care was taken to pitch them close to and equally on both sides of the sheet piling, until the stonework showed itself above the water-line, and then after the wedge-shaped upper portion had been distributed over a wider base by the action of the waves, to repeat the same process until the slopes found their angle of repose. In this way no more stone was employed than was absolutely necessary for the stability of the work, which, when completed, might be described as a mass of closely packed third-class rubble resting on a broad base, and narrowing upwards to a level slightly below the surface of the water, at which point it became a mere ridge resting against the close piling; the side slopes of its section varying from 2 to 1 near the pier heads, and 1 to 1 and $1\frac{1}{2}$ to 1 near the shore."

"The piers were completed on the 31st July, 1861, and the time employed in their actual construction was thirty-one months, exclusive of three winter months each year, during which the Danube was frozen over, and all work was suspended, but inclusive of two hundred and seven days, during which it was impossible to work on account of stormy weather. The length of the north pier is 4,631 feet, that of the south pier 3,000 feet, and the depth of water in which they are built varies from 6 to 20 feet. In their construction 200,000 tons of stone, and 12,500 piles have been employed, and the cost per lineal foot has not exceeded ten guineas. The stone was a hard blue limestone, and was transported fifty-eight miles by water, after having been for the most part carted two miles to the river bank at Toulcha. None of the stones were heavier than two men could lift, or less in size than a common brick, and their highest price delivered at the piers including all charges was five shillings per ton, and the lowest price was four shillings per ton. All the longitudinal and transverse timbers, as well as the planking and fender piles, were of oak, and their cost was at the rate of two shillings and three-pence per cubic foot, while the fir piles were delivered ready for driving for four-pence per cubic foot. Labour, two shillings and sixpence per day, and carpenters, four shillings and sixpence per day."

After these works had withstood the action of the sea for over ten years, during which time a little additional stone had to be

deposited from time to time to replace material displaced during storms, the piers having also been lengthened to the extent of about 1,100 feet to increase their efficiency, it was found that the timber in the upper part of the works was becoming decayed; it was therefore decided to replace the upper timber work with a solid concrete top. (Plate 13, figs. 17 and 18.) This was accordingly done; the old timber serving as a stage upon which to carry out the work of consolidation. It was found that the rubble deposited against the piles had become completely consolidated by the growth of mollusca, and could not be removed except by blasting. The concrete superstructure was therefore founded upon a practically solid bed of rock, and all danger of settlement was removed. The outer end of the jetties were further protected by depositing a number of concrete blocks on the sea face.

There are several points of special interest in connection with these works deserving of notice. By carrying them out in timber with a rubble protecting mound, it was possible to complete the works in a minimum of time, and the benefit to be derived from their construction was at once realised. Moreover, the sheet piling prevented the stones on the outer face from being washed over into the channel, and a much smaller amount sufficed. The timber being sufficiently durable to give the rubble time to consolidate before the permanent superstructure was built, the danger, or rather the certainty, of settlement in the event of the superstructure having been erected on the rubble before its consolidation was prevented. The disastrous results of building works upon a newly deposited rubble mound has already been pointed out in the early part of this paper. Again, the nature of the channel resulting from the construction of the jetties being established, the requisite strength for the different parts of the superstructure could be accurately determined, and the permanent portion of the work could be carried out with the greatest economy and dispatch. The total cost of these works from their commencement in 1858 to the present date, including extension, maintenance for 10 years previous to their consolidation, their subsequent consolidation and maintenance to 1885, amounted to the moderate sum of about £220,000, or about £34 per foot, the total length of the two jetties being 8,789 feet.

Their small height above the level of the sea, namely, 4 feet, enabled the crest of the large waves in time of storms to pass over,

and thus destroyed their recoil, and therefore prevented the displacement of the rubble on the sea face to a great extent.

Previous to the construction of these works there was only a depth of from 8 to 10 feet over the bar; since their construction the depth for many years past, unaided by dredging, has not been less than $20\frac{1}{2}$ feet.

From a study of the history of the above successful works there can be little doubt that a modification of the system carried out at the Danube with such satisfactory results could be successfully carried out in connection with our numerous bar-bound rivers, and at a figure much below what is popularly supposed would be required for permanent improvements, and, when it is considered how important it is for the advancement and prosperity of the colony that the splendid coast districts should be opened up, the day cannot be far distant when, profiting by the experience of others, which, in some cases, has been dearly bought, our natural advantages and facilities for carrying out works of such importance will be understood and appreciated, and the natural, though by no means insurmountable, difficulties in connection with the access to the water highways and main lines of communication to so important a part of our territory will be things of the past.

Harbour improvements in the United Kingdom and many other countries are carried out under local Harbour Boards. In Great Britain the money is advanced to the Harbour Boards by the Public Works Loan Commissioners on the security of the rates and harbour dues, and is paid back to the Commissioners on the sinking fund system. Thus, if the money is advanced at 4 per cent., the Harbour Boards pay the Commissioners $4\frac{1}{2}$ per cent., which, on the principle of a sinking fund, liquidates the debt in about 56 years. If the Board paid 5 per cent. the debt would be liquidated in about 41 years. This system enables the local boards to gradually relieve themselves of debt, and in time the public reap the benefit by a reduction in the harbour dues.

The great advantage as far as cost of carriage of bulky goods by sea as compared with railway carriage enables produce to be transported by sea when, if it was necessary to forward the same by railway, the cost of carriage in the latter case would completely swallow up all possible profits to the producer. Mr. A. W. H

Bailey, President of the Manchester Society of Engineers, in his recent presidential address, estimated the cost of propelling a ton of freight by sea or land under most conditions as follows:—A ton of goods can be sent a distance of 2,000 miles by water at a cost equal to that of 100 miles on land.

When the above facts as to the relative cost of sea and land transit are considered, the great advantage that would accrue from works permanently securing the safe navigation of our numerous coast rivers must be apparent to all. Again, the relative cost of improving the river entrances and constructing a coast railway is a matter for serious consideration. The average cost per mile of our existing railways has been about £12,500. The author, after a very careful study of the question, is of opinion that the entrance to the Richmond River, which has been spoken of as one of the worst, if not the worst on the coast, could be permanently improved, and a good entrance channel secured for a sum not exceeding £220,000, and that most of the other rivers could be treated for a considerably smaller figure. In other words, the cost of treating the worst river entrance on the coast would be equal to the construction and equipment of $17\frac{3}{4}$ miles of railway.

In conclusion, it only remains to acknowledge the sources from which this paper has been compiled. The author has availed himself of the valuable information contained in the various volumes of the Minutes of the Institution of Civil Engineers, the reports of the Chief of Engineers of the United States, several copies of which having been most generously presented to him by the Chief of Engineers, the following reports recently published by the authority of the Imperial Parliament:—The reports of the Select Committee on Harbour Accommodation for 1883 and 1884, the report of the Sub-Committee on the most suitable place for a Harbour of Refuge on the East Coast of Scotland, besides other articles and publications. He has also to express his thanks to our worthy Hon. Sec., Mr. G. Fischer, who kindly undertook the work of preparing the illustrations for lithography.

DISCUSSION.

Mr. Poole, remarked :—The importance to the people of N. S. Wales of a careful and earnest consideration of the best methods, both scientifically and financially, of permanently improving the bar harbours along our coast, could not in his opinion be over estimated. Therefore, any thoughtful and well directed discussion upon this subject was a national gain, the more so when it was remembered that the bar entrances, at all times intricate and sometimes exceedingly dangerous, were the means, and sometimes the only means, of access to some of the richest agricultural and mineral districts in the world. Unfortunately the gravity and importance of this subject had been considerably weakened in its hold upon the public mind, by propositions more or less earnest, to construct coast railways in order to transport the produce of the coast districts to Sydney. Now, without troubling the Association with a tabulated statement, contrasting railway and coasting steamship rates for transport, and without accepting absolutely the conclusions of Mr. A. W. H. Bailey that a ton of goods could be sent a distance of 2000 miles by water at a cost equal to that of 100 miles by land, still the advantage of water over land transit was so obvious as to need no further illustration. Then what must be said of the proposals to construct coast railways, which from the very nature of the position, had a greater mileage than the transit by water. He would take two cases as an example of the whole. First, from Sydney to Newcastle by water was at the outside only 70 miles, by rail via Homebush and Waratah 104 miles, difference in favour of water carriage, 34 miles. Second, from Grafton to the Tweed by water 100 miles, by surveyed railway line, 165 miles, difference in favour of water carriage, 65 miles. Surely these two examples were sufficient to show the unwisdom, financially at least, of constructing coast lines of railway to compete with shorter water carriage ; and conversely the wisdom of earnestly considering the best way to facilitate the transit of produce by water by deepening and protecting the entrances to our bar harbours. To effect this desirable result, the engineer would be called upon to deal with and master some of the most difficult and complex problems to be found within the whole range of the profession, and although the success and failures of the past might be, and indeed ought to be, as guides and beacons for the future, still no ready cut and dried rule could be laid down to meet any particular

case. The engineer who aspired to be something more than a mere copyist, must study for himself, thoroughly and carefully, the whole of the vast natural forces surrounding each particular position, and the play of these forces upon each other. It would, he thought, be readily admitted that he ought, first, to make himself acquainted with the configuration, even to the most minute details of the site of the proposed works; second, the maximum velocity and force of the waves; third, the strength and direction of the littoral current, and the consequent movement, if any, of the shingle and sand along the beach; fourth, the range of the tides; fifth, the angle at the point of intersection of the river and sea; sixth, the maximum and minimum discharge of the river; seventh, the nature of the base upon which the works are to rest, and eighth, what effect his works would have upon any or the whole of the forces just mentioned, and of these forces upon his work. Moreover, it was not enough that a temporary improvement only was obtained; permanent improvement should be the only aim; and withou entering into the merits of the various methods of breakwater construction, so ably dealt with by the author of the paper we were now considering; or the suitability of any one of these methods for any particular breakwater for the protection and improvement of any river entrance along our coast, he might, however, venture to say that no permanent improvement would be obtained in any case unless the work were carried sufficiently seaward, so as to bring the outlet or point of discharge within the reach of the littoral current, otherwise a new bar would, in all probability, be formed just beyond the head of the work, and then it might be found exceedingly difficult to extend the works on the old lines and effectually maintain the nozzle action on the new bar.

There was still another matter of great importance, that was the judicious selection of the material to be used in breakwater construction, and upon this subject he quoted from the Treatise on Civil Engineering, by Henry Law, C.E. At page 122, he said :—"A very important branch of the science of hydraulic engineering, as applied to the construction of seaworks, is that connected with the chemical action of the salt water upon materials immersed in it. Some stones and mortars not only when immersed, but also when exposed to the sea air, may often be noticed to decompose and to become covered by an efflorescence of the carbonate of soda, resulting from the action of the hydro-chloride of soda in suspension in the atmosphere, or in combination with the water upon the carbonate of lime. The hydro-chlorides of

magnesia present in sea water act in a very peculiar manner upon some stones and mortars, for when the former exist in the state of protocarbonates of lime, the magnesia enters into combination with it, and as during that process a new crystalline arrangement takes place, it is frequently the case the stone disintegrates. With the argillo-calcareous stones, however, this action does not take place, and it would appear that the combination of the lime with the alumina is sufficiently energetic to enable the stones in which that state prevails to resist the decomposition of the sea water. The same remarks apply to mortars and cements, for it is found that unless the mortars made with ordinary limes are perfectly carbonized before being immersed, or unless the cements be obtained from natural argillo-calcareous rocks, or if artificial, unless the lime and alumina have been made to combine intimately by the effects of fusion, however well they may appear to resist in the commencement, they will eventually be certain to disintegrate. At Algiers, Brest, Cherbourg and the Ile de Rhé, some mortars were employed for the formation of large blocks of concrete, and were composed of moderately hydraulic limes mixed with artificial puzzalanos, prepared in accordance with Vicat's suggestion, merely by exposing clays to a low heat, in such a manner as to allow free access of air to all the parts in incandescence. The concretes thus made resisted satisfactorily for some time, but at the expiration of two or three years, they fell to powder; whilst in all cases where the natural puzzolanos have been employed they have not yielded. It appears, therefore, that there are certain changes produced in the alumina by the action of intense heat which render it more capable of combining with lime, and it is probably in this manner that we may account for the admirable result obtained by the application of the Portland cement." "The most important observation to be made with respect to the employment of metals in sea water is, that under no circumstances should any two different kinds be employed in contact with one another. In such cases a galvanic action takes place, by the intervention of the salt waters, which produces very rapid and important chemical decomposition."

Mr. Laing said the subject of Mr. Shellshear's paper on Breakwaters and Training Jetties, was a very important one, and must interest, not only the members of this association but the public generally, for it affected more or less the material interests not only of N.S. Wales but of the whole of Australia, and the great amount of information he

had collected and laid before us, with lithographs of various works referred to, deserved from the members the careful study and time necessary for a clear conception of the work, and an intelligent discussion of the various methods adopted to carry out such works to a successful issue, and dealing as he had done with the subject, under two seperate headings, we were enabled to examine better in detail the parts of most importance to ourselves at present.

Speaking of breakwaters, Mr. Shellshear gave the preference to the monolithic system, and as he said, we learn most from failures, he gave us two examples of failures in that system, and although the improvement of cement and other requirements of concrete works had changed the character of such works, and also the time and money requisite to carry them out, the two failures mentioned, Wick and Madras,* go to show that the importance of sound foundations still holds good. Before leaving this portion of the subject for the present, he would remark that Plymouth breakwater was commenced in 1812, and finished in 1841. It was formed to protect the exposed face of a natural harbour, and cost £1,500,000 sterling.

Cherbourg, on the French coast, was an artificial harbour (said to be the greatest and most costly work of its kind) was finished about 1856, was over 70 years building, and cost over £2,500,000. It was the first of our modern marine works in which cement was used to a large extent.

With respect to Dover, a Commission, which sat in 1844, recommended that £2,500,000 should be expended in forming an artificial harbour of refuge at Dover, and the works now being carried on, as described by Mr. Shellshear, were the result of that recommendation.

These three harbours showed the time and money devoted by England and France to such works, and we had now, young as the colony was, commenced preparations for our first harbour of refuge. At Trial Bay the buildings for housing prisoners to be employed on the works had been completed, and the first batch of prisoners had been sent there about three weeks ago.

---

*The breakwaters at Wick and Madras are referred to in the paper as examples of the second system, namely, breakwaters founded upon a rubble base with a solid masonry superstructure, and are not examples of the monolithic system as stated by Mr. Laing.—Ed.

Let us now look at the second part, namely, training jetties. Mr. Shellshear said in page 111 "There are few countries in the world where works of this class are more urgently needed than in New South Wales," and further on in the same page, he says :— "The objects to be attained by the construction of training jetties are to confine the inlet and exit of *tidal* and upland waters within definite limits, and to obstruct the progress of sand, as it tends to force its way across the entrance of a river by the action of the waves." and in page 92 he said: "Recent investigations tend to the conclusion, which is in accordance with observation, that every wave is more or less a 'wave of translation,' setting down each particle of water, or of matter suspended in water, a little in advance of where it picked up that particle, and thus by degrees producing that heaping up of waves which gather on a lee-shore during storm. This property of waves accounts for the facts that, although they tend to undermine and demolish steep cliffs, they heap up sand, gravel, shingle, or such materials as they are able to sweep along, upon every flat or sloping beach against which they directly roll, that they carry such materials into bays and estuaries, and that when they advance obliquely along the coast they make the materials of the beach travel along the coast in the same direction,"—and in the next paragraph he said : "The extent to which waves acting obliquely along a coast cause the materials of the beach to travel is well illustrated along the coast of New South Wales, where at almost every inlet sandspits are found forcing their way across the entrance by this action." These quotations formed, he thought, a clear statement of Mr. Shellshear's case, that the entrances of our rivers on the east coast were filled up by deposit from the sea; this there could be no doubt was correct, and it was also true that the coast presented an oblique lee-shore to all our storm winds, and also that all the rivers having, like "Richmond" river, a north headland at the entrance, present not only an oblique, but also a *dead lee-shore to all* our storm winds.

Having now looked at the cause of the deposit which closed the entrances to our rivers, we would look at the proposed remedy, which, although an estimate of cost was given, was not clearly stated in the paper, and we could only, as the American says, "guess" the method by the examples quoted, and which were said to be applicable in treating our rivers. We could not, therefore, judge the proposed treatment on its

merits without plans. We could only enquire and judge whether the conditions of the coast where these examples occur were the same, the cause of deposit the same, and whether the means which remove the obstructions formed by the deposits were also available on our rivers.

In page 111, Mr. Shellshear said: "Within the last few years the Americans have made great advances in the science of constructing raining jetties, as along their extended seaboard they have many rivers obstructed by shifting sand bars, under circumstances much less favourable for successful treatment than is the case with the rivers on our coast; for, although the rise and fall of the tide is about the same, the distance to which the shallow water extends is much greater on the coast of America than it is with us." And after describing the works at Charleston on page 114, he goes on to say, "There are many other works now in progress on the American coast, including the great works at the mouth of the Mississippi, where a depth of about 40 feet was secured, against a former depth of only 8 or 9 feet;" and further on in the same page he remarked, "The American system of construction could no doubt be applied with advantage in treating the rivers of New South Wales, although there might be some difficulty in the manufacture of the fascines, as there is not the same abundance of suitable material available." We could observe by these passages that he was very favourably impressed with the conviction that the American mode of treatment would apply to our rivers, but as he was still more favourably impressed in favour of works on the Danube, and he intended to confine his remarks on the comparative condition of our coast and rivers to that of the Danube and Black Sea, into which it falls, he wished before leaving the American works to state what the Mississippi was, for the works on it were identically the same in principle as the works on the Danube.

The Mississippi from its entrance to the source of the Missouri, which falls into it, was over 4,000 miles in length, and, with its many branches, drained a basin of 1,250,000 square miles, which was four times the total area of New South Wales. The *Scientific American* of the 15th May, 1880, said: "The 33 navigable rivers of the Mississippi system comprise 14,000 miles of navigable waters, intersecting or bordering on 18 states and two territories, and up to 1878 18,500,000 dollars (equal to £3,700,000) had been spent in improvements."

It had annual periodical floods, which rose as much as 40 feet at the head of the plain and 20 feet at New Orleans, and thousands of acres of

land with their growth of timber on the banks were annually carried away by the current, and formed into shoals at the mouth, and in 1882 a disastrous flood took place, which left 75,000 persons destitute.

It would be appropriate to state here, for reference, the length of some of our own rivers, as stated in an essay on New South Wales by G. H. Reid, Esq., M.P. The length of the Hawkesbury was 330 miles, Hunter 300 miles, Manning 100 miles, Macleay 190 miles, Clarence 240 miles. The length of the Richmond was not given. It had two arms, but measuring the branch on which Lismore was situated, the distance on the map in a straight line from the mouth to the source at Mt. Lindsay was from 60 to 65 miles. Of course it was a winding river, and the actual length was much greater. Lismore was distant from Ballina 70 miles by river, but only 20 miles by land. All of these rivers were subject to floods after a heavy rainfall, but none of our east coast rivers had annual or periodical floods. The Manning River he was not acquainted with, but the Hunter, Macleay, Clarence, and Richmond rivers had all large storage for tidal waters in proportion to their lengths, but it should be borne in mind that the small tidal range on our coast, which as Mr. Shellshear said, "reduces the difficulties of construction," reduced also the rapidity of tidal scour. Let us now look at the river Danube. In page 114 of Mr. Shellshear's paper he said, "Another system of constructing works, and one that is eminently suitable for the successful treatment of our rivers, is the most ingenious plan adopted in the case of the now famous works at the Sulina mouth of the Danube. These works are among the most economical and successful works that have ever been carried out, and having stood the test of nearly 30 years contest with the elements, a somewhat lengthy account of their construction, maintenance, and consolidation should be of special interest." He quite agreed with the favourable opinion of the works expressed in the above quotation, but as to whether they were "suitable for the successful treatment of our rivers," that was a different question, and required further inquiry, and information in answer to the following questions: First, were the shoals at the mouth of the Danube formed by deposit from the rivers or from the sea? Second, were these shoals removed by scour derived from tidal waters or by the concentrated force of the annual flood waters of the river? The second might be answered by simply stating that the Danube falls into the Black Sea, which has *no tide,* and the river has annual periodical floods caused by the melting of the snow

and ice formed in the winter months, but, from its important bearing in the treatment of bar harbours, the second question, as well as the first, would be better answered by a quotation from Sir C. A. Hartley's paper, from which Mr. Shellshear had taken the description of the works. The paper was read by Sir Charles (then Mr. Hartley) before the Institution of Civil Engineers, March 11th, 1862, and published in the *Artizan* the following month. Mr. Hartley said : "The Danube, after a course of 1700 miles, during which it received more than 400 tributaries and drained 300,000 square miles, passed in a single channel 1,700 feet wide and 50 feet deep, the Bulgarian town of Wakeha. . . . . During high floods the inclination of the surface waters of the Sulina has 3 inches per mile, while during extreme low water it did not exceed one inch per mile. At times of ordinary high waters, when the current had obtained the velocity of from $2\frac{1}{2}$ to 3 miles an hour, the Danube before it divided at Ishmail Chatal delivered a volume of water equal to nineteen and a half million cubic feet per minute, while in the dry season, when the current was reduced to one mile per hour, the flow did not exceed seven and a half million cubic feet per minute. At times of extraordinary floods, such as that which occurred in March, 1861, the velocity was increased to 5 miles per hour, and the volume of water then delivered amounted to sixty million cubic feet per minute, or eight times the quantity discharged at ordinary low water. It was stated, as the result of careful observation, that when the waters were most surcharged, they carried to sea at the rate of 1 cubic inch of sedimentary matter, supposing it to be solidified into coherent earth per cubic foot of water, and that not more than one-fortieth part of this proportion was transported when the floods had subsided. Thus, at the former period, upwards of 600,000 cubic yards of alluvial detritus passed into the sea by the several mouths of the rivers in twenty-four hours, and at the latter not more than 15,000 cubic yards. The results of these investigations accounted in a great degree for the changes which took place from time to time in the positions and extent of the sand banks forming the bars across the several mouths."

The second question was, were these shoals removed by the scour of tidal waters, or by the concentrated force of the annual flood waters? As he said before the Black Sea had no tide, therefore there could be no tidal scour, and labour was not interrupted or increased in cost by tidal range. With respect to the flood waters Mr. Hartley said: "Although

there was a great difference of opinion as to the merits of the three principal branches or mouths, all the technical authorities who had studied the question on the ground, agreed in recommending that whichever mouth was chosen, the system of improvement should be that of guiding the river water across the bar by means of piers projected from the most advanced dry angles of the mouth, so as to concentrate the strength of the river current on the bottom of the proposed improved channel by an artificial prolongation of the river banks into deep water." After giving the description of works quoted by Mr. Shellshear, Mr. Hartley went on saying, "In April, 1858, when the works were commenced, there was a navigable channel only 9 feet deep over the long shoal forming the Sulina bar. In November, 1859, when the works had been brought to a close for the winter, the north pier had advanced 3000 feet, and the south pier 500 feet, and there the depth on the bar was 10 feet, which was increased to 14 feet by the following April, although the works had remained stationary. Hopes were consequently entertained that the action of the north pier would in itself be sufficient to maintain an improvement; but these expectations were disappointed, as in August, when the north pier had reached a length of 4600 feet, the depth on the bar had diminished to $9\frac{1}{4}$ feet. Every exertion was then made to bring the opposite pier into play. Accordingly, during the next three months the south pier was advanced 1500 feet, and as it was within 600 feet of the north pier the good effect of concentrating the whole force of the river current on the bar became at once apparent, thus on the 30th of November, 1860, there was a navigable channel of 12 feet, and on the 28th February, 1861, of 16 feet. Then came the breaking up of the ice in the river, and the furious descent of the extraordinary high floods which caused so much damage at Galatz and submerged the whole delta; but this time, instead of the depth on the bar being diminished, the swollen waters confined between the two piers, and directed in a proper line, fairly swept away the remains of the bar on to the south bank and into deep water." It would be seen from these quotations that these shoals were formed by the river waters, and removed by the concentration of the discharge of the river waters, they, the floods, being the prime factors in both cases. Mr. Shellshear informs us that after 10 years the piers were lengthened 1100 feet. He contended they would require to be lengthened periodically, the time might be longer or shorter, in proportion to the depth of the sea when the river water was discharged, and the surface area of the bottom over which the

alluvial detritus was spread by the action of winds and current, but 600,000 cubic yards of matter, or even 15,000 cubic yards per day could not be discharged in one place day after day for years without forming a shoal in the place of deposit.

The question now remaining to be dealt with was, how can the Richmond River be made a highway for trade, safe and open at all times in all weathers ?

The matter could be dealt with, he thought, in two ways, viz., by canal joining it to the Clarence River, or by training walls, breakwater, and dredging, to contract and clear the entrance.

The entrance of the Richmond was one mile wide, and it was on a dead lee-shore to all our storm winds and waves, as he said before, with the north head standing out nearly 5000 feet to the eastward, intercepting the sand carried along our coast by the storm, to all of which it was open, and by which it is blocked with this sand. A remark made by Sir John Coode in a report on the Timaru breakwater in New Zealand, was very appropriate in this place, it was as follows : "In order to be successful the travel of the shingle northward must not be interfered with." There were scattered rocks outside the north head, and also a large rock with 9 feet of water on it, termed middle ground ; it was about 1500 feet south-east of the north head, and it seemed to him that if the entrance was to be rendered accessible in all weathers, it would have to be done on the principle so successfully adopted for Newcastle Harbour, viz., with inside training wall on north side, say from pilot station to the south end of rock termed middle ground, this wall would be 4000 feet long, and on the south side a training wall and breakwater from the upper end of Mangrove Flat to the south spit breakwater, from there past the north training wall, leaving a passage 1500 feet wide, trending round in a north-easterly direction until it came in line with the north head to divert the sand past the north head and outlying rocks, and prevent the storm waves dashing vessels on the lee-shore. This training wall and breakwater on south side would be $2\frac{1}{2}$ miles long. One half of it would be in deep water, and the entrance would not be so well protected as the entrance to Newcastle, for even with the length stated there would be troubled waters at north head in an easterly gale. The cost of this breakwater he would scarcely like to say. The last 1650 feet of breakwater outside of Nobbys, at Newcastle, cost about £60,000, rather over £36 per foot run.

In 1879, Sir John Coode reporting on the Belfast harbour works at the entrance of the river Moyne flowing into Port Fairy as reported in *Australian Engineering and Building News*, 1st September, 1879, said: "The construction of a work nearly, if not quite, 3000 feet in length would involve an expenditure of not less than £450,000 or £500,000," this would give a cost of about £166 per foot run, and would be a nearer proximate of the cost of an effective breakwater at Richmond River entrance, than that of the breakwater at Newcastle would be.

The other method which could perhaps be adopted would be to cut a canal joining the two rivers, Clarence and Richmond. The Clarence entrance was more easily dealt with, and bringing the waters of both rivers into one channel, and concentrating expenditure on one entrance, a better port might be got for less cost. This, of course, could only be determined after a careful survey, not only for the best place of cutting and the cost of a canal, but also as to the effect the flow of the Richmond into the Clarence would have on the fertility of the district below the junction of the canal. The Richmond River being a very winding river watered a large space in its course, the distance from Ballina to Lismore being 70 miles by river and 20 or 22 miles by land; and no doubt the river had a great influence on the fertility and value of the country through which it passed.

He now wished to show what had been done at the entrance to the Hunter River. Having a southern headland at entrance, and the change caused by training walls and good breakwaters carrying the storm water and sand past the entrance, and by judicious dredging, one plan would show the condition of the place in 1816, when the greater portion of it was sand flats, the second plan was one showing the condition of the port in 1883, with a city built on its banks and accommodation in the harbour for from 50,000 to 60,000 tons of shipping. Exclusive of coasters, in 1883, 656,906 tons of shipping came into, and 926,596 tons left Newcastle.

He closed his remarks by reading a report, dated 16th June, 1882, from the Harbour Master at Newcastle to the President of the Marine Board, Sydney, taken from a return laid before Parliament in 1883.

The Harbour Master, Newcastle, to the President, Marine Board.

Harbour Office, Newcastle, 16th June, 1882.

Sir,

I have the honor to forward for your information copies of soundings in the fairway of this harbour, taken under favourable circumstances, 27/4/81 and '82, which shows a steady increase in the depth of water over those taken in 1880. This serves to confirm my opinion expressed in letter on that subject, dated 30/4/80. The increased depth of water is owing to the very large amount of dredging done in the harbour, thereby admitting a large volume of water, which has greatly increased the scouring influence, between the southern breakwater and the northern retaining wall (or breakwater). The latter has had the effect of removing a large sand-spit, which was partly above water, running out from Scott's Point, and caused a very dangerous eddy that does not now exist. Where it was dry, there is now 8 feet of water at low tide, and I have no doubt that, if the retaining wall is kept in repair, there will soon be 20 feet, thus giving about 150 feet more width in the narrowest and most intricate part of the harbour.

The North Channel still continues to increase in depth through the same influence. I may note that the much dreaded Oyster Bank, abreast of Nobby's, is now a thing of the past; where there was only 7 feet there is now 19. All these increased depths in the fairway and North Channel, where the dredges have never been employed, must be the result of extensive dredging in the harbour, which has caused a great scour in the fairway, as already expressed.

I have also forwarded copies of soundings taken across the harbour in 1860, with those taken on the same lines of bearings, in May, 1882; which must be interesting to all concerned, as they show the enormous quantity of silt that has been removed, to obtain the present accommodation. You will observe the position of the red buoy on the south elbow of the Horse-shoe, where there was only $4\frac{1}{2}$ feet, there is now 20 feet at low-water; also, the white buoy on the north arm of the Horse-shoe, where there was 10 feet there is now 21 feet at low-water. Both of these buoys have been removed, being no longer required. The deep water extends a considerable distance to the westward beyond what is shown on the chart, until the end of the high level coal staiths comes in line with cathedral.

Within a short distance off the wharf, there is not less than 23 feet across the harbour, over a sand-bank that formerly dried at low water (see chart enclosed) ; but, notwithstanding all that has been done, a great deal more space is required to meet the requirements of the large ships and steamers now visiting this port.

It was only a few days ago that 50,000 tons of shipping were safely moored in this port (which proves its capabilities), that a few years ago was a mass of sand-banks forming dangerous eddies and intricate navigation. Such is the result of judicious engineering, which has made this once dreaded harbour to be perfectly secure and safe to enter or leave by day or night.

I have, &c.,

D. T. ALLEN,
Harbour Master.

Mr. Shellshear, in reply, remarked that the danger of the bar re-forming in front of works at river entrances was confined to the case of shallow seas where the depth was small for a long distance from the shore, but in the case of our rivers the depth increased so rapidly seaward that there was no probability of any trouble on that score if the bar was once removed.

No doubt great care would have to be exercised in the selection of cement for sea works, but at the present time there was no difficulty in getting cement of suitable quality with proper supervision.

The question of the time taken to construct sea works was not of so much importance in the case of breakwaters as it was with training jetties, for, as a rule, breakwaters were built on sites which are, so to speak, permanent, but training jetties were erected where the nature of the bottom is constantly varying, and therefore if training jetties were not pushed forward with dispatch great additional expenditure would be incurred.

Reference had been made in the paper to the Mississippi and Danube works, and some little misunderstanding had arisen as some of the speakers had confused the question of the constructive details of the works with the action that training jetties produced. In the case of a river flowing through a delta into a tideless sea, training jetties protected the entrance from the action of the waves, and con-

centrated the flow of the river in a definite channel, and as far as the action of the waves was concerned, the works performed the same function whether there was a tide or not. It had been stated that with our small range of tide it would not be possible to get a sufficient velocity over the bars to remove the sand, but the question of velocity was one that depended upon the proportion that existed between the tidal capacity of the river and the width of the entrance, and by contracting or expanding the width of entrance, the velocity of tide could be regulated to any required extent. Sir John Coode recommended works somewhat similar to those at the Danube for the improvement works at the entrance to the Gippsland Lakes, and these works were now in progress. This entrance was quite as exposed as the river entrances on our coast.

Referring to the extension of the piers at the Sulina mouth of the Danube, it should have been stated that the piers, as originally carried out, did not both extend the same distance seaward, and it was found necessary to extend the south pier out the same distance as the north. There was also a cutting back action at the shore end of the north pier which necessitated that pier being extended landwards for some distance ; but no extension has been found necessary in addition to the original length of the north pier seawards.

The works going on in America were designed to give the current a sufficient velocity to clear the channels without dredging. Reference had been made to Newcastle ; there could be no doubt that Newcastle had been greatly improved, but at that place the harbour had been improved by protecting it with a breakwater, which enabled dredging to be carried out under the protection of the works ; over 6,000,000 tons had been dredged from that harbour, so the improvement could not be looked upon wholly as the result of improved tidal scour. If our smaller rivers were to be improved at any reasonable cost, the only system upon which this could be done, was by the induced tidal scour produced by the construction of training jetties, as the expense of constructing protecting breakwaters, and then dredging a channel would be too great to come within the means of the districts through which the rivers flow.

Port Fairy (Belfast, Victoria), was referred to by one of the speakers. The works recommended by Sir John Coode in 1879 were for the formation of an outer harbour, and not for the improvement of the river.

The velocity of tide through the Dublin entrance was $3\frac{1}{2}$ miles per hour, and had been found sufficient to maintain the entrance and remove the bar.

The following table, founded on those given by Du Buat and Beardmore, shows the approximate velocities at which water will move various material

Velocities.			Material.
Feet per Second.	Feet per Minute.	Miles per Hour.	
0·50	30	0·34	Will just move fine sand.
0·70	42	0·49	,, ,, ,, coarse sand.
1·00	60	0·68	,, ,, ,, fine gravel.
2·25	135	1·53	,, ,, ,, pebbles 1 inch diameter.
3·34	200	2·25	,, ,, ,, ,, $1\frac{1}{2}$ inch diameter.
4·00	240	2·72	,, ,, ,, heavy shingle.

15th APRIL, 1886.

ON THE USE OF CONCENTRATED SOLUTIONS OF SODA FOR GENERATING STEAM.

By C. WAGEMANN, C.E.

Some two years ago the attention of the engineering world was attracted by a discovery made by Mr. Moritz Honigmann, the proprietor of a large soda factory at Aix-la-Chapelle (Germany), and since that time the patented inventions based upon that discovery have not only been tested by a great number of trials, but have been set into practical working, and two years' experience has shown that we have to add a new chapter to the science of engineering. Mr. Honigmann's invention will, no doubt, revolutionise the present mode of generating steam in all cases where steam is required in large quantities, or steam-power is to be transmitted from its source to either stationary or moving working-places, or where a high degree of safety is required.

Before entering into the matter it may be advisable to recall to memory a few physical laws.

It is well known that the various liquids have different boiling points. That of water (under mean atmospheric pressure) lies at 212° F. At this temperature the water is expanded to such an extent that a further addition of heat introduces a power sufficient to neutralise the pressure of the atmospheric air, to decompose the globules of water and to transform them into steam. If the water is exposed to more than the common atmospheric pressure, say to that of 2 atm., steam-making begins at a temperature of 2768 F., under a pressure of 3 atm., a temperature of 291° F. is required, and a temperature of 365° F. is corresponding to 10 atm. pressure. A reduction of the atmospheric pressure lowers the temperature for

evaporating, In a partial vacuum of ½ atm., a temperature of 180° F., and in that of 1-10th atm., a temperature of 115° F. is sufficient to raise steam.

The boiling-point of solutions of caustic soda (Na O. HO.) in water depends on the degree of concentration. The following table shows the boiling-points of a few soda-brines (under mean atmospheric pressure), and the pressure of steam (generated from water) of the same temperature :—

If the soda-brine consists of:				The boiling point is:	The pressure of steam of equal heat is :
100 parts soda	and	400	parts water	224·6 deg. F.	0·3 atm.
100 ,,	,,	300	,,	230·6 ,,	0·4 ,,
100 ,,	,,	200	,,	248 ,,	0 95 ,,
100 ,,	,,	120	,,	276 ,,	2 ,,
100 ,,	,,	100	,,	291 ,,	3 ,,
100 ,,	,,	80	,,	309 ,,	4·2 ,,
100 ,,	,,	70	,,	319·1 ,,	5·1 ,,
100 ,,	,,	60	,,	330·8 ,,	6·1 ,,
100 ,,	,,	50	,,	338·9 ,,	7 ,,
100 ,,	,,	40	,,	365·9 ,,	10·2 ,,
100 ,,	,,	35	,,	378·5 ,,	12·1 ,,
100 ,,	,,	20	,,	428·9 ,,	
100 ,,	,,	10	,,	492·8 ,,	

It is evident that the boiling-points of the various solutions must become of higher or lower temperature if a higher or lower pressure is acting on the brine.

As only a small quantity of caustic soda is soluble in cold water, but large quantities are readily dissolved in hot water, the preparation of highly concentrated solutions is executed by heating a low-graded brine and thereby evaporating a portion of the water. One part of the heat thus introduced into the brine escapes with the evaporated water, another one serves to raise the temperature of the brine, and the (very considerable) remainder is bound in the brine as latent heat. By again diluting the concentrated brine the latent heat is set free, and (so far as it is not used for raising the temperature of the diluting water) it forms a stock of heat ready for any heating purpose.

Suppose a common vertical boiler, partially filled with water of about 210° F., be inserted in an open vessel containing a heated

soda-brine which is composed of 100 parts soda and 20 parts water (boiling-point 428.9° F.), a certain amount of heat will be transmitted from the brine into the boiler, and its contents will generate steam. By adding water to the brine a new quantity of heat i generated, and the pressure in the boiler must rise, or (if the steam is allowed to escape from the boiler) fresh steam will be generated therein.

This process can be continued until the dilution of the brine is so far advanced that its boiling-point does not sufficiently surpass the temperature of the steam which is to be generated. For a further continuation of steam-making, either the diluted brine must be exchanged against concentrated one, or it must be admitted that the steam may leave the boiler under lower pressure than during the first period of the process. Such an apparatus could be used in cases where steam is to be generated in places where the use of fire is absolutely prohibited (for instance, in powder-mills), but it needs no special calculation to show that the price of power generated and transmitted in such manner is too high for extensive practical use. The missing link, for making the above combination, a superior boiler was added by Mr. Honigmann, who observed that soda-brine absorbs without any noise, and condenses instantaneously and completely large quantities of steam introduced into it, provided the temperature of the steam remains below the boiling-point of the soda-brine.

The addition to the above apparatus of a pipe conducting the waste-steam of an engine (instead of water) into the soda-brine, alters the whole aspect. All heat stored in the brine is now utilised, and what is not converted into labor in the cylinders of the engine is returned to the brine, and (as the quantity of heat generated by the dilution of the brine is greater than that which is converted into labor) the pressure in the boiler must rise. In fact, the boiler must be supplied with water during the working of the engine, if a constant pressure shall be maintained.

It appears quite unnecessary to enter into calculations for demonstrating the enormous saving of fuel by this process. Suffice it to point out that the latent heat of the waste steam—which, fos instance, represents in steam of $1\frac{1}{2}$ atm. pressure 528 calories (centigs.) out of 630 calories total heat—is completely saved,

On the other hand, inquiries must be made as to the *quantity of fuel used for evaporating the water* from the diluted brine. This, of course, depends upon the construction of the concentrating appliances. For the tramway motors at Aix-la-Chapelle the concentration is executed in a vessel of the shape of a Cornwall boiler, wherefrom the evaporated water escapes into the open air. By careful observations, it is stated that one pound of common Westphalian coal (which is able to convert, in a well-constructed boiler, 6 to 8 lbs. water into steam) is able to concentrate such a quantity of brine as is required for making 7·1 pounds of steam in the boiler of a tramway engine. This is, so far, a very satisfactory result, as it shows that with a most inferior concentrating apparatus the Honigmann boiler possesses a steam-making capability per pound of fuel at least equal, if not superior, to that of any good boiler. The reason why the useful effect is not higher must be found in the loss of heat carried in that steam which is evaporated from the concentrating vessel. And here Mr. Honigmann succeeded to reduce it, by aid of a very ingenious arrangement, to nearly *nil*. Instead of allowing the steam from the concentrating vessel to escape into the open air, he carries it through a number of pipes which are crossing a tank filled with diluted cool brine; thereby the steam is condensed, and the condensed water forms the best material for feeding the boilers. At the same time the diluted brine in the tank is heated and some water evaporated. The latter operation is supported by a small vacuum-pump, which makes a partial vacuum (of $\frac{1}{4}$ to $\frac{1}{10}$ atm.) in the (closed) tank, and thereby raises the temperature of the brine therein to 122° and 176° F. respectively. The waste steam of the vacuum-pump is also conducted through the pipes crossing the tank, and assists heating the brine, oonsequently nearly no heat of any steam generated is lost. The Cornwall boiler (destined for concentrating the brine to the degree finally required) is fed from the brine-tank, which is placed about 24 feet high. The latter feeds itself automatically through a pipe which leads to the bottom of a reservoir standing so much below the said tank that the vacuum generated in the latter is sufficient to suck up the diluted brine. This apparatus (with three large Cornwall boilers) has been in use for a long time at Mr. Honigmann's factory for making concentrated soda-brine; and on the 23rd April, 1885, Mr. Gutermuth (Assistant at the Royal

Technical Academy at Aix-la-Chapelle) has ascertained that the quantity of water evaporated from the Cornwall boilers was 776 cubic feet, and that the quantity of water evaporated by the vacuum-pump was also 776 cubic feet, which shows a saving of 50 per cent. Considering all possible losses, and the heat used for driving the vacuum-pump, the saving of fuel in the Honigmann process must be at least 40 per cent., and the quantity of steam generated by one pound of common Westphalian coal must be 11·9 lbs.

An important question is that of the *influence of soda-brine on the boiler material.* A series of experiments has proved that soda-brine does not attack iron at temperatures below 313° F. If, therefore, steam of low pressure (4 atm.) is used, boilers and soda-vessels can be made of iron. If steam of higher temperature is required, the soda-vessels must be made of copper or brass, which stand the influence of soda-brine at any temperature. Fortunately the brine-vessel can be very light, as it is exposed to a slight pressure. The boiler is comparatively small, and its heating-surface can be obtained by using field-tubes made of brass.

If the soda-boiler is used on locomotives, it is essential to ascertain *the quantity of brine which must be carried* on it to enable it to work for a certain length of time without a renewal. Suppose the waste steam be below 2 atm., the corresponding heat is 276° F. A soda-brine with boiling-point of this temperature consists of 100 parts (by weight) soda and 120 parts water, its specific gravity is 1·41 (1 cb. ft. = 88·8 lbs.), and 220 lbs. are measuring 2·5 cb. ft. If for the condensation of this steam a soda-brine shall be used, with boiling-point of 492° F., viz., a mixture of 100 parts soda and 10 parts water (spec. gr. 1·89; 1 cb. ft. = 117·9 lbs.), 110 lbs. of *this* brine measures 0·93 cb, ft. The difference between these two cubical contents, viz., 2·5—0·93 = 1·57 cb. ft. must represent the quantity of water to be introduced into the concentrated brine for diluting it to such a degree that it cannot condense any longer steam of 2 atm. pressure. Or 1 cb. ft. brine of 492° F. boiling-point is able to absorb 1·7 cb. ft. of water *if the process is going on under atmospheric pressure.*

It is already mentioned that with all liquids the boiling-point rises if the liquid is exposed to higher pressure, and Mr. Honigmann found that the capability of absorbing steam increases considerably if

soda-brine is exposed to pressure. For instance, in the above case, the quantity of water which can be absorbed by brine which is exposed to $\frac{1}{2}$ atm. pressure is $1\frac{3}{4}$ times, and if exposed to 1 atm. pressure it is 3 times that which can be absorbed in an open vessel, viz. :—

1 cb. ft. of said brine absorbs in an open vessel 1·7 cb. ft. water.
1 ,, ,, ,, under $\frac{1}{2}$ atm. pressure 2·975 ,, ,,
1 ,, ,, ,, ,, 1 atm. pressure 5·1 ,, ,,

Of course these maximum pressures do not appear but at the end of the operation, and the average becomes very low if another highly interesting invention of Mr. Honigmann is made use of, who adds to the soda-brine (in the soda vessel of the locomotive) a quantity of protoxide of iron. During the time the concentrated brine is running into the brine vessel, a cock on top of the latter is opened to allow the air to escape, and when the charging of the brine vessel is completed and the air-cock closed, a partial vacuum (of 1-10th to $\frac{1}{4}$ atm.) is generated in the brine vessel by the protoxide of iron (Fe O) absorbing oxygen from the air (remaining over the brine) and being converted into peroxide of iron ($Fe_2 O_3$). This vacuum lasts about one hour, and at the end of a $4\frac{1}{2}$ hours' trip the gauge shows a pressure in the brine vessel which amounts in the locomotives used at the Aix-la-Chapelle tramway to 1-5th atm. Mr. Honigmann estimates the loss of power caused by the average back pressure on the piston to less than what is required in fired locomotives for the steam-jet which gives the artificial draft.

Consequently by allowing at the end of the operation a small amount of back pressure, the duration of the process, with one charge, can be multiplied, or, for a given duration, the quantity of brine carried can be reduced at the same ratio.

Moreover, the presence of protoxide of iron in the brine vessel and the absorbtion of oxygen by it prevents oxydising of the copper.

The *capacity of the soda boiler to generate steam is very great.* In February, 1885, trials were made with one of the Aix-la-Chapelle tramway engines, in the presence of Professor Wullner (Rector of the Royal Technical Academy, Aix-la-Chapelle) and other prominent engineers to decide upon this question. The vertical boiler of the said engine is about 20 inch high, and of 4 feet diameter; it has 120 field tubes of 1·6 inch diameter. The boiler is screwed on top of

the brine vessel of the same diameter and 55 inch-high. The weight of the boiler and soda vessel, including water and brine, is 3 tons. During the trials the engine and one carriage (with hand-break put on) were going at a very high speed, and as even then the maximum capability of steam-making could by far not be utilised, *a part of the steam was* (*without passing the engine*) *directly conducted into the brine* and condensed. The quantity of steam was in one case 2,400 lbs., in another 2,700 lbs. per hour. During the trials the heated surface (field tubes surrounded by brine) was on an average 107 square feet, the difference in the temperatures of brine and water was 12° F The 107 sq. ft. surface generated on an average 2,500 lbs. steam per hour, or *one* sq. ft. made 23 *lbs. steam*, whilst one sq. ft. in a common stationary boiler raises from 3 to 7 lbs., and in a locomotive boiler 8 to 10 lbs. steam per hour.

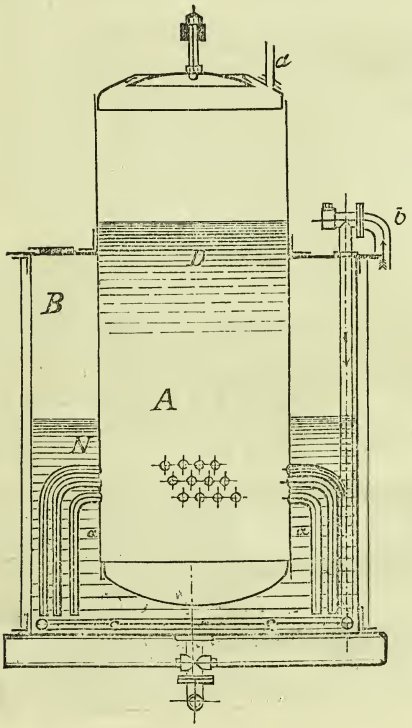


FIG. I.

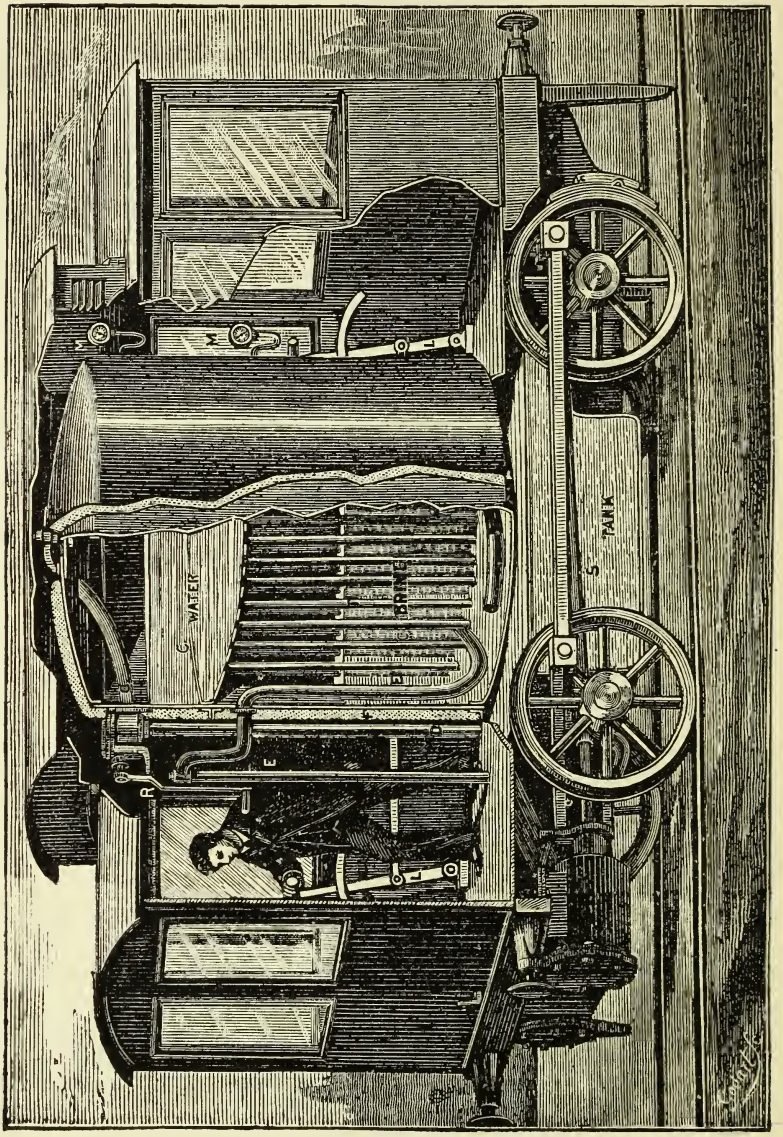


FIG. 11.

This superior steam-making capability renders the soda boiler especially fit for engines which require a sudden increase of quantity or pressure of steam, and has been one of the reasons why it is now in use at the St. Gothard Tunnel.

One of the first boilers Mr. Honigmann constructed for tramway locomotives is shown in Fig. 1. The boiler (A) and the soda vessel (B) are of iron, as the intended pressure was 4 atm. only. The waste steam entered the brine through the pipe (C), which ends in a perforated coil (C), whereby the steam is equally distributed through the brine.

Honigmann's improved engines at present in use on the tramways at Aix-la-Chapelle are shown in Fig. 2. The iron boiler (C) has a strong copper bottom, and 125 field tubes made of brass inserted in it. The steam passes through the pipe (D) and a regulating valve (R) into the cylinders of the engine. The waste steam returns through the pipe (E) into the brine. Boiler and soda vessel are coated with a non-conductor (F), and (S) is a tank for feeding water, (L) the usual reversing gear, and (MM) are pressure gauges. The principal dimensions are as follows, viz. :—

No. of horse-power	15
Diameter of cylinders (two)	7·87 inch.
Stroke	8·65 ,.
Diameter of wheels	19·68 ,,
Diameter of vertical boiler	47·25 ,,
Height ,. ,, ...	20 ,,
Diameter of brine vessel	47·25 ,,
Height ,, ,, ...	55 ,,
No. of field tubes of 1·6 inch diameter ...	120 ,,
Heated surface—	
When starting	58·8 sq. ft.
At the end of the operation	107·4 ,,
Cubical content of boiler	19 cb. ft.
., ,, brine vessel	52·28 ,,
Space for feeding water	17·65 ,,
Steam pressure	3 to 5 atm.
Quantity of water which can be converted into steam by one charge of brine ...	28·25 cb. ft.
One charge of brine lasts	6 to 7 hours
Hauling force	1,012 lbs.
Weight of boiler and soda vessel, including water and brine	3 tons
Weight of engine	6 ,,
Weight of carriage	2½ to 3 tons

The tramway between Aix-la-Chapelle and Burtscheit has a length of 3,280 ft. without any level parts, the gradients are—

1312	feet	1 : 30
820	,,	1 : 43
1148	,,	1 : 72
3280	feet.	

There are 4 curves of 65 feet radius.

Cost of plant and daily expenses are as follows, viz. :—

CAPITAL.

4 engines each, M 9000	M 36,000	
Concentrating station	M 5,000	
	M 41,000	£2,050

DAILY EXPENSES.

10 per cent. on M, 41,000, interest and wear and tear	M 11·30
Wages for 4 engine-drivers at M 3·50...	M 14·00
,, 1 fireman	M 3·00
,, 1 workman	M 2·60
Lubricating oil, grease, &c.	M 3·00
2400 lbs. coal at M0·40	M 9·60
Repairs	M 4·50
	M 48.00

Or per engine (only 3 engines are running) M 18·00, and as such engine is making 62 miles daily the expenses per mile are M 0·29, or about 3½d.

A large locomotive engine is running daily since October, 1884, a passenger train on the *railway* from Aix-la-Chapelle to Tulich and back (33¾ miles). It has the following dimensions, viz. :—

Diameter of cylinders	23·6 inch
Stroke	24·4 ,,
Diameter of wheels (3 pairs coupled)	47 ,,
Diameter of soda vessel	6 ft. 6 in.
Length of soda vessel	19 ft. 8 in.
Weight of engine	45 tons.

The locomotive superintendent of the Aix-la-Chapelle Railway Company certifies that at a trial made in 1884, this engine hauled a goods train over the line in regular time as per time table. The train consisted of 22 carriages, its total weight was 191·7 tons, whilst the maximum weight allowed on this line for fired locomotives of 45 tons weight is 180 tons. Generally, he says, it is proved that the capability of the soda locomotive is *at leust* equal to that of a fired locomotive of same weight.

Two other engines of the same construction are now in use at the St. Gothard Tunnel.

The practical usefulness of Honigmann's boiler must be acknowledged in face of the facts: That locomotive engines fitted with them are in regular service since two years in Aix-la-Chapelle (railway and tramway); that, in consideration of the highly satisfactory results obtained therewith, the municipalities of Leipzig and Halle have adopted Honigmann's system for their tramways (see *Illustrated Leipzig News* of 23rd January, 1886, and Sydney *Evening News* of 22nd March, 1886); and that two engines which were imported from Germany, and tried on the tramways in Chicago, have given fullest satisfaction to the Directors of the Chicago Tramway Company (see *Railroad Gazette* of 5th February, 1886).

The soda-boiler has passed the experimental stage, and local circumstances (as high wages, expensive fuel and water) can only favor its introduction. No doubt other cities will soon follow the example of Aix-la-Chapelle, Leipzig, Halle, and Chicago, by adopting it for their tramways, especially those which are condemned to see their main thoroughfares like blacksmiths' workshops, filled with smoke, steam, and dirt by the fired steam motors, and the property adjoining such thoroughfares considerably reduced in value. A true expropriation without compensation! The nuisance with this kind of tramways is too well known here to enter more fully into its description; but it may be of some interest to observe the influence of an adoption of Honigmann's boilers on the weakest point of the present system—*i.e.*, its financial results.

The *Sydney Morning Herald* of the 24th March, 1886, states, on official authority, that the weekly expenses for one Baldwin motor, *ex*cluding interest and wear and tear, amount to £31 1s. 7d. This sum includes the following items, viz.:—

Wages for firemen (fourteen shifts)	£5	12	0
Coke	6	7	9
Water	1	3	7

In consideration that with soda-boilers no fireman is required, that 40 per cent. of fuel and nearly all water is saved, but that about one-tenth of a fireman's wages (for the concentrating station) must be added, the weekly savings per motor must amount to £8, or, for 50 motors, per annum, £20,800.

This financial result will be more favorable still if the heavy Baldwin motors, with their elephant-shaped cars, are replaced by a greater number of *light* Rowan cars, with soda-boilers and light engines (total weight, 9 to 10 tons against 33 tons of the present trains), carrying about 50 passengers and running in short intervals. This would meet the wants of the public better; and there is no reason why the services of the conductors should not be dispensed with, provided the cars being properly constructed. If an omnibus-driver is smart enough to attend to his horses, and at the same time to control the door and the fare-box, and to give exchange whilst driving in streets crowded with vehicles and foot-passengers, it would be an insult to doubt the capability of engine-drivers to superintend, *at the stopping-places*, the door, and the fare-box, which can be placed near the engine compartment. To avoid the collection of additional fares at the end of the sections, control-tickets could be issued. Passengers on the suburban railways do not complain of being compelled to buy tickets to keep them during the voyage, and to deliver them when leaving the train, even if the distance is ever so short. Why could not the same be done by tramway passengers? An absolute control would be exercised if each passenger would be obliged to put his fare for the *whole* trip intended into the fare-box when entering the car, and to receive a control-ticket (thin brass-plate), which he had to put into a second fixed box when leaving the car. It needs only to issue, on lines with two or three sections, control-tickets of two or three colours respectively, and with the numbers 1, 2, or 3 punched out, to ascertain at any place of the line whether a passenger has paid the correct fare or not. Moreover would this arrangement offer the best means for obtaining exact returns as to the number of passengers who have been travelling on the various sections of the lines. The traffic department could make use of such statistics for regulating the number of cars to be placed on the various lines in conformity with the real demand. The soda-boiler simplifies the duties of the engine-driver so much that he finds sufficient time for collecting fares and issuing control-tickets, without leaving his place in the engine compartment, whilst the tram stops. The wages of 150 conductors (for 75 cars) would thereby be saved,—viz., more than £23,000 per annum.

These savings on wages for firemen and conductors, on fuel and water will, with those made under the heading "repairs of roads" and "repairs of rolling-stock," doubtless turn the present balance of the tramway accounts from the wrong to the right side without increasing the fares, and without an expenditure of £200,000 for heavier rails which otherwise must be taken into consideration very soon.

Not only for tramways, underground railways, mines (especially coal mines) the soda boiler is of prominent importance, but also for stationary establishments where large quantities of steam are used. The savings of 40 per cent. of fuel represents during one or two years such large figures that even in establishments of medium size the first outlay for the concentrating station with vacuum-pumps will soon be repaid.

There is also another large field for the use of Honigmann's process still, viz., that of steam-drying and over-heating, the latter process being extensively used now in many industries for drying purposes, and would be used more still if, with the present appliances, it were not connected with danger. For drying or over-heating steam a coil of the steam-pipe is placed into a brine vessel containing concentrated soda brine, and a small portion of waste steam is introduced into the brine, which is to be renewed from time to time. No danger is attached to this process, as the temperature of the brine is only a few degrees higher than that of the steam, and as there is no pressure in the brine vessel. Besides the over-heating can be done with the greatest accuracy, the regulation being done by simply regulating the quantity of steam introduced into the brine.

Sometimes it is desirable to combine the apparatus for concentrating brine with the soda boiler. This arrangement is made on various locomotives, and also on a "steam-buggy" Mr. Honigmann built. The brine vessel in this case is used alternatively as concentrator and for heating the boiler. For instance, at the steam-buggy a small fire-box is attached to the bottom of the brine vessel, and before starting the soda brine is (in a place where the smoke does not inconvenience the public) heated until the safety valve of the boiler blows off (at 8 atm.) More water is now injected into the boiler, and thereby the pressure lowered to 4 atm. The buggy is then ready for a trip of 15 to 18 miles, at the end of which the pressure in the boiler is 4 atm. still, that in the soda vessel about 1 atm.

For men-of-war, and especially for torpedo boats, where high speed and absence of smoke for a certain time are of greatest value, the above combination cannot be surpassed. The diluted brine is concentrated in the brine vessel under 3 to 4 atm. pressure. The steam generated thereby is used for driving the ship's engine at low speed, and in case steam of high pressure is suddenly required, water is injected into the boiler proper. Steam of very high pressure is generated therein at once, whilst the pressure in the soda boiler disappears in consequence of the brine being cooled. The engines can now work under high pressure, and without fire and smoke. This mode is very saving as the steam is used twice. That a speed can be obtained which it is impossible to attain by any fired boiler is proved by those experiments (already referred to) which were made to show the superior steam-making capability, and whereby it was stated that a soda boiler is able to generate for a certain time three to four times the quantity a good boiler of same heated surface is able to produce.

Professor Riedler (University at Munich) says at the end of his paper read in 1883 before the Society of German Engineers :—"In consideration of the favourable results obtained by Honigmann's process, it must be acknowledged that it contains so many qualities of practical value that its application will be extended over a very large field, the limits of which cannot be exactly estimated at present. In ships, for small motors (used in dwelling-houses), for heating purposes it will come in use, but in the first instance the soda boilers will soon be used exclusively for tramways, underground railways, in mining and tunnelling, where the present means for transmitting power are suffering from so many deficiencies that none of them could come into general use."

MINUTES OF PROCEEDINGS.

13th MAY, 1886.

Walter Shellshear, President, in the Chair.

The following candidates were balloted for and duly elected:—

Members:

R. P. PARK.
V. RHODES.
E. S. NIXON.

The following Papers were then read:—Mr. Angus Mackay on "The Mechanics of Agriculture," and Mr. H. Selfe, on "Our Colonial-Built Harbour Steamers."

THE MECHANICS OF AGRICULTURE,

By ANGUS MACKAY, Memb. Franklin Inst.

Agriculture has advanced in two very distinct lines during the hundred and fifty years since the science emerged from the long dark period during which the cultivator of the soil was the drudge of the time, whose main efforts were dependent upon his own manual strength.

Those two lines are chemistry and mechanics. The former has done much for agriculture, tending as it has directly and in the most effectively practical manner, to make clear and plain what, prior to the days of agricultural chemistry, was dark and mysterious, and beneath the consideration of learned men in early times, with but rare exceptions. Chemistry, fortunately for agriculture, was fostered and encouraged by public as well as by the individual efforts of the many grand and noble men who employed their talents in that direction during late years. In the various schools opened for agricultural instruction, chemistry has been recognised as a leading principle, and due attention has been paid to it.

But mechanics, as applied to agriculture, have not fared so well. With the exception of the American agricultural schools, and notably those of New York, California and Illinois, comparatively little has been done for educating the farmer in agricultural mechanics. And the impression has gone abroad that while mechanics and engineering have done so much for the industries

generally, agriculture is far behind in that respect. The supposition is not correct. As we shall see while investigating and illustrating this department of agriculture, the aid afforded to the science by mechanical engineering is nothing short of wonderful. And it will be seen further that the skilled agriculturist of the present day should of necessity be an efficient mechanic, or mechanical engineer. The tendency of all agriculture is in that direction very decidedly, and towards further advances. And there is ample scope still for improvement.

So far, the developments of agricultural mechanics are due very largely to private effort, and to the pushing business tact of the many individuals and firms who have made specialties of the agricultural tools and machines manufactured and brought into notice by them. Progress of that kind is not without its advantages; hence the credit given to those who have been the direct me ns of many of the immense advances made in the form and quality of farming tools and machines generally. But the process has its disadvantages. It has led to the palming off upon the classes who cultivate the soil of immense numbers of machines and contrivances which actual work prove to be absolutely unsuitable for the purposes for which they were recommended and pushed into notice. Worry, loss of time and money, and disappointment follow the purchase of bad and unsuitable tools and machines. But, in spite of all drawbacks, the farmer has now the choice of tools and machines equal to the best seen in other countries.

The author's object then in drawing attention to the foregoing facts is twofold:

First, in order to show the effective services already extended to agriculture by mechanical developments in the form and quality of the tools and machines in use.

Secondly, to show further that mechanical skill is absolutely necessary to the agriculturist of every degree, that he may be able, from his own knowledge, to decide whether an implement offered him is suitable in a practical way for the work to be done; that he may be able to use his implements to the best advantage, and to make such repairs, alterations, or improvements upon them as may become necessary. It has been a boon to agriculture that implement makers and others have done so much; it is still better when the agriculturist himself is a skilled mechanic—the two divisions are combined in the one man with great advantage.

The Royal Agricultural Society of England, and the Highland Society of Scotland, have done much for the development of agricultural mechanics and engineering. Those societies offered prizes, not only for such machines as were coming into use, but for special contrivances for doing specified work, and by this means many very desirable improvements have been introduced. Other societies, in Australia as well as in other places, have followed in the wake of the great institutions of the mother land; but the latter have always been most prominent, a circumstance due largely to the exceptional ability of the men the Royal and Highland Societies were able to secure as experts and judges. The most notable case of this kind in Australia as yet, was the very handsome offer of the Government of South Australia for the invention of a harvesting machine that would reap the grain, thresh, winnow, and bag it, all in the field. The author had the privilege of seeing that trial, and, although none of the machines submitted came up to the requirements of the case, he was much taken with the very great skill and enterprise made manifest by the competition.

South Australia is peculiarly adapted for wheat farming on an immense scale, and upon a system in which mechanical engineering is all important. The only parallel to South Australia is seen in parts of California and in Colorado. The South Australian wheat soils, with but rare exceptions, are very light. The soil is loose in texture, and very rich in lime. It overlies immense beds of limestone. By the aid of gang ploughs—a series of two or more light plough bodies in a frame—the soil is turned over four or five inches deep, each furrow being from 8in. to 10in. wide, a team, with two men and four to six horses, going over from four to ten or more acres daily. Seed is at once sown by centrifugal seed sowing machines, doing from 50 to 100 acres daily, and in very excellent style. The crops grown are light in quantity, from six to ten bushels per acre being about the average; and the harvesting is done by stripping machines, reaping 200 to 400 bushels daily. The grain is threshed, winnowed, and bagged in the field by different machines. Altogether the system is peculiar, and would not be rated as high-class farming in either Europe or America. But it is adapted to the light, open treeless lands of South Australia, and sections of Victoria and New South Wales. The results, per man, that is, the number of bushels produced per man and horse engaged,

are not low by any means. The whole process offers excellent illustration of what mechanical aids are doing for wheat farming. It is very safe to say that, without their peculiar ploughs, their seed sowers (the author had the privilege of introducing them to Australian farmers), and their harvesting appliances, it could not pay, possibly, to reap 10 bushels of wheat per acre. But by the South Australian system, six bushels pay. The author has not a doubt that, with further mechanical aids for ploughing deeper, and when manuring or soiling enters into their system, much larger returns will be got for about the same outlay.

The principles of agricultural mechanics are identical with the science of mechanics. The lever, wedge and screw, have all their outlets in agricultural engineering, in the same manner, precisely as in the other branches of mechanics. In the plough, in seed sowing machines, in mowers, reapers, hay cutters, baling presses, and the other machines used in agriculture, the knowledge, the practice and theory of mechanics is as useful as in shipbuilding, railroad engineering, or other branches of the art.

In the spade, mattock, pick, trenching, draining, and other tools of that type, we have the very first principles of the lever and wedge. To be effective, to move soil with the least exertion to the worker, and to enable him to get the best results, the tools should not weigh an ounce more than is necessary for the strain put upon them. Quality of material, steel, iron, and wood, and substance where required only, rather than weight and bulk, should guide in the choice of tools of that kind, even more than in those used for horse, steam, or other mechanical power.

The plough is a combination of the wedge, screw, and lever, and just in proportion to the skill of the maker in developing those principles of mechanics in the plough, each in the right proportion and in the right place for the work to be done, and these in combination with the quality of material used, go to make the most suitable plough. But different soils require differently arranged implements, whether the work be breaking up new land, ploughing where stumps and roots cannot be got rid of for a time—then the stump-jumping plough of South Australia is a boon—ploughing for ordinary crops, subsoiling, draining, ditching, tank-making, and other ploughing, for each class of work special adaptation of the implement is necessary. And in these days it is better and cheaper,

to an absolute certainty, to provide suitable tools than to worry men and horses, and waste time and money trying to get along with tools that are not suitable.

In stump-extracting and tree-falling machines, sometimes termed "forest devils," we have most excellent results from the application of lever power. By a combination of levers and chains, or by the use of the screw, trees and stumps are taken down, or raised out of the ground by one or two men—or horses can be used—these contrivances are able to tear out of the ground stumps, roots, stones, &c., that could not be moved by a 10-horse power engine without the aid of the lever or screw.

Seed sowers combine the the screw, lever, and centrifugal force in such a manner as to sow, with mathematical regularity, from 50 to 100 acres of wheat daily, one man and a horse doing the work.

Mowing, reaping, binding, stripping, threshing, winnowing, and other machines of that type, are all built upon the recognised mechanical principles followed in other classes of engineering, The rule for quality and suitability of the materials in the machine apply in these with even greater force than in ploughs. Every pound of unnecessary weight, every unnecessary combination or increase of parts all tell against complicated machines of this kind. Steel and iron (now-a-days capable of endless applications in mechanics) are decidedly better than wood in all machines in which jolting, dust, and risks of wear from friction of the parts are combined with very rapid speed. Machines of this kind have been improved immensely since their first introduction in Australia, nine years ago, and improvements still go on steadily. The results already are that the white man, with their aid, is able, even in these depressed times for grain, to hold his own in the market in competition with grain from Russia, India, and other cheap labour countries.

Draining has developed an immense variety of tools of the spade, or wedge and lever type, to every one of which the features apply of quality and weight of material dealt with in the treatment of spades and digging tools generally. In no department is improvement in these respects more marked than in draining tools. Draining itself has opened out other developments in the science of agriculture. Prior to 1750 it seems to have been scarcely known that water in the soil is only beneficial to agriculture while it is in a state of movement. Stagnant water is now known to be injurious to

vegetation, to crops, grasses, and the animals upon or near where water stagnates. When this fact became evident to the advanced British agriculturist of 130 years ago—and there were some advanced men in those times—open ditches were made to carry off the stagnating water, and during some sixty years open drains and ditches were supposed to answer all the purpose. Then another advance was made by laying stones, wood, &c., in the lower part of the drains, filling in the soil, and cultivating the surface. The effect was surprising. The land about the drains was found to be easier to work, it became warmer in winter, and cooler in summer, and gave much better returns.

1836 saw the first tile drains laid. Pipe drains followed soon after. Now it is known that not only does draining carry off stagnating and undesirable water, but the soil is deepened, and the drained land withstands drought, while undrained land becomes parched and bakes hard as bricks. The ordinary spirit level and a length of straight-edged batten are ample levelling instruments for ordinary draining, and so well is the work done that capable drainers can open a pipe track 6ft. deep, 4in. at bottom, and 22in. at top, and lay in the pipes without a speck of loose earth about them, until the work is ready for filling in.

Irrigation can be successful only where the soil is thoroughly drained, either naturally, by having an open sub-soil, or artifically by means of pipe drains. California, Colorado, Utah, and other States of the Union, with climate very much like that of Australia, have advanced rapidly with irrigation. Victoria, our neighbour, is also moving ahead, as are a few enterprising men both in New South Wales and in Queensland. Irrigation is applied successfully for grain crops, grass, orcharding, &c. The mechanical engineering principles involved are easily understood, and with care are not difficult to work out. From lake, river, or dam, water is led in open ditches with a batter of about 45 degrees, where the fall does not exceed 6ft. per mile. Where the fall is greater, or gullies, &c., have to be crossed, flumes made V shape, and of timber, or close pipes of wrought iron or steel (made up to 40in. diameter) are used. Ploughs and scoops are employed with good effect in opening out the ditches. When the water is got to the place where it is to be used, it is brought upon the land with as little run or fall as possible, otherwise it would quickly cut the land into gullies, wash away the soil,

and be worse than useless. What is termed terracing is used where steep land has to be crossed. The terraces are made by putting boards or bags across the ditch, so as to raise the water a foot or so. The water from each terrace flows out from an opening in the centre of the board, which is really a dam. Efficient levelling when water can be run upon land, is done by the water itself, always being careful not to allow it to run too fast, nor cut away the land. This is a special branch of our subject to be dealt with separately. Here it is necessary to add that, in practice, it is found the best course to saturate the soil say two, three, or more times during a season, rather than to wet the surface oftener. For wheat and other grains, two saturations are found ample to secure crops; once after the seed is in, and again when the crop is in flower. But much depends upon the soil and the season. There is no hard and fast rule for guidance.

At a strawberry farm in Santa Clara, California, the author saw the effects of irrigation from artesian wells, and the necessity that exists for using water only after it has been exposed to the air. Indeed, it is doubtful whether water applied direct from wells could be profitable for irrigation. In the case under notice an immense tank of concrete has been raised some 10ft. above the level of the cultivated land, which is level plain of great extent. In this tank the well water is aerated, and the elevation is sufficient to give water pressure sufficient all over the cultivation land.

The sugar business is much indebted to engineering. The improvement made during the last twelve years, both in the speed of doing the work and the cost of production, is nothing short of wonderful. The quality of the product is also vastly improved. Yet there are many openings for farther advances. The author will mention one only on this occasion—the want of a machine to cut down cane in the field. There is a fortune for the man who perfects a contrivance of that kind. The difficulties in the way are all of the mechanical kind, and they are to be overcome by the man who studies the subject carefully, but it must be in the field, and while the crop is being harvested.

OUR COLONIAL-BUILT HARBOUR STEAMERS.

By H. SELFE.

In bringing this subject before the association the author desires chiefly to consider what progress has been made during the last twenty years in the construction of our harbour steamers, and to suggest in what direction there is room for further improvements which would render them more suitable for modern requirements. To do this it will not be necessary in the scope of this paper to enter into detailed calculations, but simply to look at the benefits derived from the improvements of the past, and see how they may be advantageously applied to our own steamers.

This subject opens up such a wide field, containing as it does so many and various matters affecting it, that the author feels he cannot give the numerous points the individual attention they deserve, but, being aware that many of our members are conversant with its various aspects, hopes that it will evoke a good discussion, which may prove beneficial.

Our newest paddle ferry steamers are not what they ought to be. Their machinery is bad in principle and unsuited for the work required of them. In endeavouring to prove this, the writer believes that although he may meet with some opposition, he will no doubt have a counterbalancing amount of support before being called upon to reply to any criticisms.

About 25 years ago there were only six or seven ferry steamers—all paddle boats—running on the waters of Port Jackson, the two of most improved construction at that time being the "Alma" and "Herald." The former, which was built of wood, till about six months ago was running successfully on the Hawkesbury River. The latter was an iron boat, imported and put together here. They both steamed from 8 to 9 knots an hour, and had diagonal high-pressure engines exhausting up the funnel. They had circular boilers, with through tubes, and carried a pressure of about 50lbs per square inch.

Let us now look at the progress we have made in the models of steamers since these vessels were built. From what we see of the old boats, it appears to have been supposed that a good floor was

essential, and, as speed was necessary, the vessels were made narrow, with the ends sharpened off, producing a good wedge-shape. This rendered them very unstable, and they had a strong inclination to remain anything but perpendicular with even a small load of passengers on deck. This model is gradually going out, and it is being realised that to insure a staunch boat the displacement must take place further from the ship's centre when she is listed, or, to take a common illustration, the difference in section is as that between a square box and a basin. In the one case the metacentre is almost stationary under all conditions, while in the other it moves from side to side as the vessel lists, and gives the long end of the lever to the high side. This improvement has to some extent been brought about by scientific knowledge, but chiefly from the increased facilities for practical experience, and there is reason to believe that our modern built screw steamers will bear comparison with those in any part of the world. It is now understood that a waterman's skiff has more stability, more room, and is altogether better adapted for our requirements than anything in the shape of a small ship. Here it may be stated that the author has long been of opinion that the day will come when our ocean steamers will be more of this form, and he considers it would be preferable to the square wall-sided tanks that it is now the practice to build. Even with the weight of their engines and boilers to balance them they now require a second bottom some feet above the proper one, and the intermediate space filled with water to make them stand upright, although their top weight, in the shape of spars and rigging, is comparatively a trifle. To propose constructing a large steamer more after the shape of a skiff would no doubt give rise to all sorts of imaginary obstacles, such as the awkward shape for internal accommodation for passengers and cargo, or for convenience for berthing at a wharf. Such objections could probably soon be overcome, and it appears that a vessel with fine symmetrical curved lines would be a much stronger structure than the present ocean waggons. It has taken us since the days of Nelson to bring ship's sides from falling inwards to being almost perpendicular, and a much shorter time will probably see them inclining outwards, and our modern box-girders with pointed ends will appear as antiquated as the old "Dreadnought."

Let us now turn to the various merits of wood, iron, and the composite system for the construction of our harbour steamers, from

which it seems that iron and steel are not used to such an extent as their present low prices and superior suitability justifies us in expecting. Hard wood crooks are naturally becoming scarce near at hand, and the necessity of going further into the bush to obtain them renders them more expensive, while on the other hand the price of metal has been steadily falling. Our slips and docks are getting more numerous, and are likely to continue doing so, which will tend to reduce the cost of keeping iron bottoms clean. Constant experimenting is going on with a view to getting a better anti-fouling paint than the orthodox "Peacock," and it is to be hoped that they may result in success. Iron and steel have the great advantage of not becoming sodden and heavy in the vessel's bottom, and dried up and open on the top sides, which is a great point in their favour compared with wood. Those conversant with the subject must have noticed that excessive corrosion, either internally or externally, is in nearly all cases due to sheer neglect or parsimony on the part of owners. Corrosion always takes place where the metal is boxed in with wood, which retains the damp, and, as in ferry boats, the space below deck is seldom used except for engine and boiler, there is no reason for closing in the sides. It is a noticeable fact that where there is a free current of air under cover there is little or no rust, and also that when the bottom inside is well covered with cement and the outside properly painted before rust has commenced, the plates will last an indefinite time. The writer has seen cement taken off the inside of a ship's bottom at the end of twelve years which disclosed the original "bloom" still on the iron, and on scraping the outside of the vessel the original paint marks on the plates became visible. Wooden frames steamed and bent are much used at present in the construction of the smaller class of our harbour steamers, but it is questionable if this mode of construction could be utilised for steamers of the size likely to be required in the future. Several vessels have been recently built on the composite principle, which have proved light in construction and satisfactory in many respects. Wood and iron, however, are bad partners under water, and contact is invariably formed between them and the sheathing metal, which soon results in the total destruction of the iron where that is the case. A coppered bottom is nevertheless necessary where the bottom cannot be got at to be cleaned, but anyone planking iron frames now, where a dock is available, will, there

is good reason to believe, regret before many years that he did not plate them.

Passing on to the design and construction of our modern boilers, we see that our screw steamers, which have practically come into general use during the last twenty years, have boilers of a shape suited to them. These boilers are nearly all circular, with circular furnaces, wet combustion chambers and return tubes. Their total length is about eight or nine feet, and working pressure from 60 to 120 lbs. However, as we are dealing chiefly with paddle steamers, as the most suited for harbour ferry service, we may write down the improvements in their boilers as a cypher. No doubt they are larger and stronger than formerly, carrying an increased pressure up to 90 lbs. per sq. inch, and modern appliances enable the constructor to put in better work. But placing the boiler of 20 years ago and our present one side by side, the only apparent difference is that the latter has double rivetted longitudinal seams, spring safety valves, and is generally constructed of steel. Perhaps we could not have done better, but it is a remarkable fact that in the design of boilers for ferry steamers we have stood still for many years.

We now come to engines. As our screw steamers are now gradually being constructed with double cylinder, surface condensing engines, which, being economical and effective do all that is required of them, we may pass them by and come at once to paddle engines.

If anyone asked why we have single cylinder engines in all our ferry boats, the most honest answer would be that the old "Alma" had a single diagonal engine, and that being a success in its day, we have been blindly following and enlarging on the same pattern ever since. It is a fact that during the last two years several ferry steamers have been built with a common diagonal high-pressure engine, exhausting up the funnel, similar in every respect to one built on Peacock's Point, Balmain, 30 years ago, except that the cylinder has been increased in diameter from 13 to 19 inches, the stroke from 2 to 4 feet, and the pressure from 40 to 80 lbs., the boat being about eight times the size. It is true that in some of our paddle engines the tandem system has been adopted, a high-pressure cylinder being put at the back of a low-pressure cylinder. A surface condenser has in some cases been added, and these improvements are gratifying, as showing that modern mechanical civilisation has in some instances pierced with a ray of light the darkness in which so many steamboat

men are content to dwell. The fact, however, remains, that in our harbour, with a constantly increasing traffic, and steamers continually crossing and coming nearly in contact with one another, not one of them can reverse their engines at once, but must stop and wait till the way is about half off the vessel before they can go astern. Contrast this with a screw steamer the author tried some time ago. She was 100 feet long, steaming 12 knots an hour, and was brought to a standstill and went astern in about 180 feet. She had a pair of compound condensing engines capable of being started and stopped by a boy, and did not require a man to pump at a heavy starting lever for every half stroke made.

A mechanical success, however great, often remains unappreciated by the general public, even though it be also a financial one, on account of its higher first cost. As an instance we may call to mind the bronze propellers introduced about three years ago, and acknowledged beyond doubt in three of our large ocean going steamers to increase the speed a knot an hour, or give a saving of 15 to 20 per cent in fuel, and yet they have not been adopted except in a few rare cases, the first cost frightening shipowners.

The compound principle has now so thoroughly established itself all over the world, and the relation of first cost and after expenses is so well understood, that one can hardly understand an engine for commercial purposes being made in such a primitive form as is adhered to in this colony, save on the ground that there is a certain feeling of security in employing something similar to what one has been accustomed to. But such is a poor reason for declining to adopt changes which have proved a marked success elsewhere.

In the construction of an engine, we, as engineers, know that one of the principal objects is to get the greatest effective power for propulsion, and that all unnecessary weight in the moving parts is robbing one all the time the machinery is in motion. Speed, consumption of fuel, and the comfort of passengers, all require great consideration, while the cost of repairs, and time lost in effecting them, are very important items. Some of the above points appear to have been much ignored in the construction of our paddle steamers, and we will now endeavour to see in what way.

A single engine, as we are aware, exerts its greatest power when the crank is almost at right angles to the piston rod, the power gradually diminishing towards the ends of the stroke where the

momentum of the paddle wheels carries the crank over the dead centres. By substituting a pair of engines with cranks at right angles, the strain on the shaft would be nearly equalised and approximately continuous throughout the whole revolution. In the latter case a much lighter shaft would be sufficiently strong and safe on account of not having to stand the intermittent strain which takes place twice in every revolution of a single engine. The paddle wheels also for a single engine have to be much stronger to allow for the variable power applied to them, and, in addition, are frequently thrown out of balance by heavy cast iron floats intended to reduce the chance of the engine sticking on the dead centre. In boats fitted with a single engine the time lost in coming alongside a wharf is very considerable, but cannot be avoided, as the driver must make sure of his engine going astern when required. This materially increases the time of transit, and, with two or three wharves to call at, causes considerable delay. This loss of time may some day prove fatal in the event of a collision; a contingency which is daily becoming more probable from our fast increasing traffic and higher speeds.

It appears to be the impression with some engineers that slip in a paddle wheel is not all loss of power, for not long since a firm in this city reduced the size of the floats on a pair of paddle wheels to enable the engine to get away faster and develop more power, on the supposition that greater speed would be attained. This seems contrary to mechanical principles in anything like reasonably proportioned wheels. The crank, crankshaft and paddle wheel form a circular or continuous lever, the crank pin being the power end, the crank-shaft bearings the connection with the weight to be moved—that is, the boat—and the water the fulcrum against which the long end of the lever in this case acts. The average thrust exerted on the boat is arrived at by multiplying the pressure on the piston by twice the length of stroke, and dividing by the circumference of the wheel at about the centre of the floats. Anything like an equal thrust, however, is only due to the weight of the wheels and their velocity. If another engine of equal power were added, with the cranks at right angles, the power would be doubled, while the strain on the crankshaft would be about the same as before, owing to its being continuous. Supposing a cogged wheel working in a rack took the place of the paddle wheels and water on which they act, we

should then have the whole power of the engine, minus the friction exerted on the boat, as our fulcum would be solid. With water, however, we have a yielding body to deal with as a fulcrum, and the smaller we make the floats the more slip there is, which, in the vessels we are considering, amounts to from 30 to 40 per cent. under the most favourable circumstances. This lost power is exerted in giving a backward velocity to the water in contact with the ship's side through which the after part of the vessel is passing, and this considerably increases the frictional resistance of the vessel. There is also another way of looking at the loss or slip when experimenting in cutting down floats under the impression that more revolutions will give increased speed, and that is, the greater the velocity of the piston the more steam will be used, and consequently a lesser pressure will be obtained, which will give a reduced thrust on the paddle shaft bearings to propel the vessel.

Considering the size of the paddle wheels themselves, to which no doubt is attributable a great loss of power, we find they have been made small in diameter in order that passengers may not be inconvenienced by the shaft coming above the deck, while in some instances it is only a little above the deck line, and the wheels are all too narrow to obtain a fair amount of float surface. Some recently constructed are notable for this defect, which is probably due to a desire to keep down the width of the boat over all, for convenience when alongside a wharf. These specimens of modern steamboat construction may be seen any day with their floats entering and leaving the water at an angle of about 45 degrees; the entering floats tending to lift the vessel, while the emerging floats tend to depress her in the water, thereby wasting a large amount of power. In the endeavour to obtain resistance so many floats are put in these wheels that none of them get solid water to act on, each being in the broken backwater of the preceding one. When anything like full speed is put on, they may be seen splashing round in a manner which gives one the impression that they were specially designed to knock the water about, instead of to get a solid hold and propel the boat. We can imagine what would be the result if our champion sculler were to reduce the blades of his sculls to three inches wide, and compare such a supposition with the paddle wheels referred to.

The two methods adopted elsewhere to prevent loss of power have been entirely ignored on our ferry steamers, viz., increasing the diameter of the paddle wheels and using feathering floats. The first of these plans is chiefly employed in America. There the diameter of the wheels is so great that passengers on the main deck walk under the paddle shaft. This allows the floats to enter and leave the water nearer the vertical position, and puts so many floats in immersion that the loss of power is very much reduced. It may be pointed out that these American boats are very fast and have single cylinder engines, but we must bear in mind the altered condition under which they work.

It is the writer's opinion that the loss of power in our paddle boats may safely be put down at about 40 to 50 per cent. as compared with our screw steamers. The maximum speed of the former seldom reaches 10 knots under the most favourable circumstances, while 7 to 8 knots on the ferries is certainly quite as much as they average, although they are all built for speed, and may be considered full powered. With our screw boats of the same size it is no uncommon thing to average 11 knots all the year round, which gives about 40 to 50 per cent. loss for paddle steamers as compared with the screw.

It is difficult to understand why none of our boats are fitted with feathering paddles, unless we accept the conclusion that it is simply because the old boats were without them, and their example has been blindly adhered to. Every engineer knows that feathering paddles are undoubtedly the best, and our steamers have reached such a size to justify their use in almost every instance. Some may say that they would be liable to damage by bumping at the wharves, but it is not necessary for the feathering gear to be connected at the paddle-boxes as it may be on the side of the wheel next the hull.

When we see one company sending home for new feathering wheels for an old boat that had worn hers out after about 25 years' service, and other companies still constructing larger steamers with wheels of the old type, we are struck with the difficulty of getting people to make a change from what they have been accustomed to.

It occurred to the writer when thinking of paddle wheels to see what Seaton had to say on the subject in his manual of Marine Engineering, and one cannot do better than quote from him. He says: "Paddle wheels with radial floats are now but seldom

employed, and only in tugs where prime cost is a paramount consideration, or in small river steamers, having comparatively large diameter of wheels and a small amount of dip, or for service in barbarous countries, where simplicity and a minimum risk of derangement is a necessity." Another authority, Sennet, in his work on the marine steam engine, published in 1885, when speaking of radial paddle wheels states: "The extreme width of the floats should not exceed one-half the width of the vessel, so that the combined width of the two paddle wheels should not be greater than the width of the ship. In sea-going steamers the width of the float does not generally exceed one third the width of the vessel. In still water the greater the width of the float the more effective the wheel, as the required area of race can be obtained with less immersion, and the loss from oblique action is thereby reduced." As a contrast to the foregoing, the following are the dimensions of the latest colonial production: Beam of boat, 18ft.; width of each float, 42in. by a depth of 18in."

It may be as well mentioned that the owners are in no way indebted to any engineering skill for this particular part of the work, but have grown into it from their own knowledge and experience.

It must not be imagined from the foregoing remarks that all our colonial built paddle steamers are equally mechanical failures, for, as has been already pointed out, a few have shown an advance in the right direction, but the majority are of the most primitive description, with no evidence of progress or improvement about them.

It is astonishing how the possession of a few shares in a steamboat company seems to make people consider themselves qualified to give opinions on the best design and proportions for the construction of a steamer. The employment of professional men, who start and get out all their proportions from a basis, and furnish a set of drawings, with weights, displacement, &c., carefully calculated, is ignored by such an individual. When he is looking after the construction he tries to get the information he does not possess by fossicking among people who he imagines know more than himself, and it is hardly necessary to say that the information so obtained is generally about the same value as the price paid for it. As orders are given on specifications which contain few details, and as the lowest tender is accepted, old patterns, cast iron cranks, and many other things that destroy the mechanical beauty and efficiency of the engine are used

It reflects very little to our credit that a rule and sketch book on board another steamer seem to have often played a prominent part in the design of some of our steamboat engines, professional etiquette having been at even a lower ebb than mechanical skill. The author could point to engines, made by different firms, in boats on Sydney harbour that are a great deal too like one another to be above suspicion, and if one is not a direct copy there must have been a wonderful similarity of ideas on the part of the designers. With one exception, all our paddle steamers are fitted with cast iron framing to their engines, which in itself is not up to the standard of engines afloat in other countries ; cast iron being avoided as much as possible in high-class machinery. We have good specimens of diagonal engines afloat on the harbour, but these are not copied, as the first cost seems to be the main consideration with some people, who cannot see that what they get cheap is not always profitable.

In conclusion, seeing that our ferries have no opposition, the writer is of opinion that the travelling public are entitled to more security from accident than is given by an engine that will not reverse and a hull without watertight compartments, which only requires to be pierced in one place to let the vessel fill fore and aft and sink.

MINUTES OF PROCEEDINGS.

10th JUNE, 1886.

Walter Shellshear, President, in the Chair.

THE METALLIC ARCH.

By FRANCIS BERGIN, B.A., B.E., Trin. Coll., Dublin.

The able address which Mr. Benjamin Baker delivered about six months ago as president of the mechanical section of the British Association should have the effect of concentrating the attention of engineers on some startling facts, the reality or existence of which had hitherto been almost completely ignored, but the importance of which it would be difficult to exaggerate: for they are associated with unmistakable indications of approaching contingencies that may lead to the most serious catastrophes, unless stringent precautionary means be adopted for their prevention. The facts alluded to are, as many of you will have perceived, those pertaining to the deterioration in quality of either iron or steel which recent experiments have conclusively proved will ultimately arise from the frequent application of even a comparatively light stress.

In 1849 Nasymth remarked that the alternate strain in axles rendered them weak and brittle. The royal commissioners who were appointed during the year 1849 for the purpose of instituting inquiries as to the suitability of iron for railway works and appliances, stated in their report that "iron bars scarcely bear the reiterated application of one-third the breaking weight without injury, hence the prudence of always making beams capable of bearing six times the greatest weight that could come upon them." Again, about ten years subsequently, Mr. Fairbairn and Professor Unwin carried out an extensive series of experiments on a 20ft. wrought iron girder which furnished confirmatory evidence as to the correctness of the results arrived at by former investigators; and, as Mr. Baker remarked, "once more the same important but disregarded facts were forced on the attention of engineers." The interesting and comprehensive experiments of Wohler supply additional grounds for our contracting an incredulity as regards the wisdom that

guided the Board of Trade authorities in framing their rules and regulations, which, it is to be feared, have been too frequently availed of to the fullest extent.

Up to the present the rules adopted by engineers even of recognised ability have been and continue to be most conflicting as regards the greatest intensity of unit stress that ought to be employed for fixing the sectional dimensions of the various component parts of an iron or steel structure. Some of the more timid and cautious members of the profession have acted on the principle of putting plenty of material into their designs, and although this practice can scarcely be regarded as being conducive to economy, it is certainly one that may be pursued with more or less impunity, provided the surplus material be judiciously distributed. Others, on the contrary, have expressed themselves in favour of extending the present legally recognised limits of stress, especially in the case of steel. But, if statistics were available, the author is of opinion that it could be shown that the majority of existing metal structures have been designed so as to barely meet the requirements of the Board of Trade regulations, at least so far as those portions of a structure subject only to tensile stresses are concerned. In framing these rules, no doubt, the Imperial Government officials were influenced by the conviction that in fixing five tons per square inch as the maximum intensity of unit stress which their inspectors would approve of in wrought iron fabrications, they were making provision for a factor of safety of four. But, if recent statements be correct, and so far we have no reason to doubt their accuracy, if it be true that neither wrought iron nor mild steel will support even one-third of their original breaking weight when tested in tension after having been subjected for some years to the reiterated application of comparatively light loads, if this fact be regarded as being satisfactorily established, we are thereby forced to admit the possibility of the more severely strained portions of existing structures not only being worked without the existence of a safety factor of four, but of even being strained beyond the elastic limit of the material employed a contingency on the momentous import of which it is unnecessary to dilate in addressing a meeting consisting exclusively of members of this association.

Of course it rarely happens that any part of either a girder or roof is required to withstand the full intensity of stress for which it was intended that provision should be made ; still, one is justified in

assuming that each of the more severely tried members of such structures will have, at some period or other of its service, to resist this maximum intensity of stress, as it would certainly be false and what might be styled clumsy engineering to base important calculations on impossible or impracticable hypotheses. But even supposing that under the most unfavourable circumstances this maximum intensity of stress were not to be realised, still, if iron and steel became gradually and continually deteriorated in quality from the frequent application of comparatively light or other loads, if these metals under the influence of strain suffer a considerable diminution in the magnitude of their ultimate tensile strength, becoming simultaneously dangerously deficient in ductility, it necessarily follows that each and every one of the existing metallic fabrications which have been designed on the girder principle and which are subject to intermittent loading, will become unequal to the duty of efficiently fulfilling the end for which they were erected, while, perhaps, as in the case of well cared structures, manifesting every semblance of stability, rigidity, and soundness.

Iron and steel fabrications are, as you well know, liable to suffer very considerably from the effects of climate, and the rapidity with which this species of decay takes place is strikingly illustrated by the following remarks, which appeared in a comparatively recent number of *Engineering* :—"The rapid decay experienced by iron bridges which are neglected has recently been exemplified in Callowhill-street bridge in Philadelphia. When lately the painters were set to work on this structure, their preliminary exertions in cleaning off the rust brought off flakes of oxide from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch in thickness. This at once revealed the extent to which the injury had already gone, and called for some attention to the necessity of an immediate survey. The fact that the weakening process had already proceeded to a dangerous extent, was shown by the vibration which was so violent that the men had to hold on when a heavy load passed over, to avoid being shaken from the swinging stages. On examination it was found that not only had rust invaded the material of the girders, but that the whole bridge which is built on a rising grade, had moved down hill so far as to tear out the top course of the upper abutment. The structure was only completed in 1875, and thus ten years of neglect has sufficed to bring it to the verge of destruction."

Although an iron or steel bridge may, in the absence of proper supervision and attention, become totally unfitted to meet the require-

ments of ordinary traffic after the lapse of a few years, especially if it should occupy a site in close proximity to the ocean, in which position oxidation would be likely to proceed and develop with more than normal rapidity. Still this oxidation or surface disintegration which, if permitted to continue its course unchecked, might be expected to ultimately culminate in the most disastrous results, is nevertheless subservient to the salutary influence of regular inspection and other precautionary expedients. It is an evil that does not exhaust the numerous resources which modern science and modern observation have placed in the hands of the engineer. It is, in fine, a phenomenon that permits of being closely observed, examined, investigated, and accurately gauged as to the extent and character of its development. Not so, however, with its prototype, the internal or physical deterioration of the metals whose properties and peculiarities we have been engaged in considering. This latter is a species of qualitative depreciation that covertly becomes increased, thus developing a treacherous and occluded weakness in what may, nevertheless, be designated a most wonderful material, which, in conjunction with the achievements of mechanical science, has enabled the skilled engineer to wield that almost incommensurable power which has wrought such a thorough and complete revolution in the habits, customs, needs, and predilections of human society.

There is, perhaps, no purpose to which iron has been more extensively applied than the construction of bridges, especially railway bridges ; and, so far as the author can ascertain, it has been the practice of wrought iron bridge designers to avoid, as far as possible, the introduction of compressive members into their designs, simply because these members not only require to be of sufficient sectional area to withstand the effects of their respective stresses due to the most unfavourable disposition or arrangement of loading, but because it is also essential for them to be efficiently stiffened in order that they may be capable of discharging their duties as pillars or struts. As the quantity of material which it is usual to appropriate for this stiffening not unfrequently amounts to a considerable percentage of the total weight of a truss itself, it is only reasonable to expect that compression members, particularly long compression members, would be dispensed with whenever it is feasible to do so. If, however, wrought iron, when alternately exposed to a tensile and compressive stress, or even to the reiterated application of a comparatively

light tensile stress, becomes brittle and suffers a considerable diminution in the magnitude of its ultimate tensile strength, it is obvious that whatever advantages or superiority it might otherwise be supposed to possess as a material for the formation of tension members in structures subject to a variable intensity of loading, are more than counterbalanced by the existence of this most treacherous quality, which, in conjunction with the effects of oxidation, may possibly, at no distant date, manifest its potency in a startling series of deplorable accidents. It may be that the majority of existing railway bridges are in a highly satisfactory condition, as most probably they are. Some may be in no immediate danger of dismemberment, whereas others, comprising those that have been more severely strained, may be on the verge of destruction, while perhaps displaying every visible indication of soundness, as would occur in the case of structures which had been regularly cleaned and painted. Lest you should be disposed to regard this latter statement as being inconsistent with the teachings of past experience, it may not be inexpedient to quote again from the address of Mr. Baker, who is beyond question a most distinguished authority on everything that pertains to the stability of iron structures. Mr. Baker, in the address already referred to, states that "it is an open secret that nearly all the large railway companies are strengthening their bridges." And again he says, "it had come under my notice as a practical engineer that if the compression members of a structure were unduly weak, the fact became quickly evident, perhaps under the test load, but if, on the other hand the tension members were weak, no evidence might appear of the fact until frequent repetition of stresses during several years had caused them to fracture without any measurable elongation of the metal."

Although we may now consider it as being conclusively established that wrought iron becomes gradually deficient in ductility and tensile strength from the repeated application of comparatively light stresses, it is equally well established that the rapidity with which this qualitative depreciation takes place is far from being proportional to the rate of increase of the average intensity of working unit stress ; and hence it is feasible to considerably prolong the life of a bridge beyond that to which it would otherwise attain by reducing the maximum stress per unit of sectional area which will be permitted to strain its tension members. The adoption of this alternative, however, would necessitate a formidable augmentation in the weight of structures which are already

in too many instances cumbrously and unwarrantably heavy, and at best, could only be regarded as supplying a means of staving off the inevitable for a few brief years. On the contrary, so far as the author is aware, it has not been recorded that either wrought iron or mild steel develope any quality under the influence of strain which would render them unsuited to being employed for the compression members of any type of structure, so that a well-constructed bridge strut, if it could be only preserved from the effects of oxidation, should be capable of fulfilling its duty for an almost unlimited length of time.

The foregoing, amongst other considerations, have led the author to the conclusion that the present ungraceful form of main girder is, except for small spans, doomed to an early decline in popularity, and that the iron or steel bridge of the future must be that in which a minimum amount of material shall be subject to tensile stresses of varying intensity, while all members so exposed shall be of minor importance, and shall admit of being replaced with the least amount of delay, inconvenience, and expense. It is, of course, difficult to say exactly what form such a structure may assume, but, so far as the writer is enabled to glean from the faint glimmer of light that may be descried in the dim distance of futurity, it seems highly improbable that any novel form of structure will be conceived capable of affording greater facilities for the fulfilment of the conditions just enumerated than the modern development of the metallic arch, such as those that have been recently erected across the Douro, at Oporto, and across the Adigi, at Verona.

The arch, as you are aware, is of great antiquity, having a most interesting history that loses itself in the twilight of tradition, and, from whatever aspect it may be considered, possesses many peculiar and excellent properties. The grace, symmetry, and beauty of modern stone arches are familiar to every traveller, especially those who have traversed the fertile plains and blooming valleys of the British Isles. The imposing bridge that spans the Dee at Chester, the magnificent stone viaducts which connect the opposite banks of the Thames at London, the celebrated Highland bridges of Telford, and the elegantly wrought granite arches that were a short time ago erected across the Liffey at Dublin, after the designs of Mr. Stoney, are structures that have gained a world-wide reputation for the harmony of their proportions, and for the feelings of admiration with which the contemplation of their manifest stability and eminent adaptability is capable of animating the reflective bystander. As regards the weather-worn

arches of olden times, it would certainly be superfluous, if not presumptuous, to dwell at any length on the irresistible fascinations of their mystic charms—to attempt to tread the paths that have been hallowed by the footsteps of so many illustrious artists, so many distinguished essayists, and so many accomplished wooers of the lyric muse.

The metallic arch cannot be said to possess such a variety of æsthetic properties as its prototype, the stone arch, Its appearance is not calculated to foster the development of poetic imagery. Neither is it likely that it will ever be assigned a prominent position in any of the exquisite pastoral scenes that may be evolved from the fertile imaginations of our landscape artists ; but, on the contrary, it possesses the inestimable advantage of being by far the most pleasing, and in most instances, the most economical form in which iron or steel may be worked into the now indispensible metallic viaduct. It admits of being erected with the greatest facility, and without centering, across deep ravines, impetuous rivers visited, perhaps, with destructive periodical floods, and in many other cases where a girder bridge could only be constructed at excessive cost, or by unfavorably contending against most formidable difficulties. Owing to its extreme relative lightness it is especially adapted to being employed for large spans, for which any description of girder reaches such cumbrous proportions in comparison to the load to be carried. For example, a pair of wrought iron bowstring girders, of 300 ft. span, designed to carry a single line of railway, would weigh about 360 tons, whereas a pair of wrought iron arch rings if erected under similar circumstances, would not weigh more than about 190 tons, which could, of course, be considerably reduced by substituting steel for iron. Again, rapid strides have been made within recent years towards bringing to a satisfactory state of efficiency some of the processes that have been patented for the protection of iron and steel from the effects of oxidation. After a little time some one or other of these methods will undoubtedly be rendered applicable to structures of any magnitude, and as the metallic arch may be designed so that its principal members shall be exposed only to compressive stresses, thereby being insured from the effects of any qualitative deterioration that may take place, the conclusion naturally suggests itself that the day cannot be far distant when it will be feasible to maintain a well designed iron or steel arch in a desirable condition of preservation for an almost unlimited length of time and without incur-

ring any but an insignificant expenditure for maintenance. No doubt there are instances, perhaps many instances, in which the abutments required for an arch would be found more costly than those which would be sufficient for a corresponding parallel or bowstring girder, but except in particularly unfavorable cases, the great saving in material coupled with its increased durability, which would be realised by adopting the former type of structure, should be capable of more than covering whatever additional expense might be incurred in making provision for the thrust which an arch truss would develop at its springings.

There is, perhaps, no problem liable to engage the attention of an engineer more enveloped in obscurity or more exclusively couched in what is to most individuals perfectly unintelligible phraseology than that which embodies the theory of the modern form of the wrought iron or steel arch truss. Some of the ablest mathematicians of the present generation have focussed their knowledge and ability on the consideration of this most interesting subject, which is daily becoming of greater importance, but they all seem to have been equally unsuccessful in bringing the results of their labours within the reach of those who find it inconvenient to cultivate an extensive and intimate acquaintance with the higher branches of mathematics. Mr. Max Am Ende contributed a very able paper to the 31st vol, of *Engineering*, on his proposed Douro bridge ; and Professor R. H. Smith published three most interesting articles on redundant structures, including the metallic arch, in the 49th vol. of the *Engineer* ; but the investigations of both of these gentlemen have culminated in long and complicated formula, the application of which would involve a rather considerable knowledge of analytical geometry as well as of the integral calculus. Certainly, these latter subjects are of very great interest, and when skilfully manipulated, can be turned to immense advantage in the hands of the accomplished engineer. They have not, however, been so generally studied as their importance demands, whilst those who were zealous enough to acquire a familiarity with them during school or college days have had so little opportunity of utilising their knowledge, that it has in a great many instances lapsed into so unmanageable a condition as to surround the chances of success in dealing with compound integrals and other mathematical matters of a kindred nature with an unpleasant degree of doubt and solicitude Under these circumstances it must be highly desirable that some method should be devised which would enable us to dispense with the higher branches of mathematics

when engaged in determining, approximately at least, the stresses in the several members of an open webbed metallic arch or abutting truss, similar to those represented by the diagrams in Figs. 1 and 4.

The determination of stresses in any description of truss which is non-redundant, and which is allowed to move horizontally on its bearings is, under ordinary circumstances, an operation that permits of being performed expeditiously and with almost mathematical precision. But in the case of structures rigidly fixed on their bearings, and which consequently develope an abutment thrust, the task of proportioning the sectional area of each member to the maximum stress it will have to withstand becomes a matter of considerable difficulty, and can only be effected by resorting to one or other of the established tentative methods, none of which are capable of yielding absolutely correct results. For example, if the ends of the truss delineated in Fig. 1 were permitted to move freely on their respective supports, nstead of abutting as represented, only three forces would have to be considered when calculating the stresses produced in the extreme bays by any system of vertical loading, namely, the vertical reaction of either abutment and the stresses in the bays themselves. As these three forces are necessarily in equilibrium when the structure is stable, and as the magnitude of one of them, the vertical reaction may be readily determined from the given distribution of loading, that of each of the remaining two may be ascertained by simply drawing an ordinary triangle of forces according to the method so fully explained in the author's paper on graphic statics, which was read before the members of this association at the March meeting of last year. But, should the structure be erected as shown in the figure, an additional force of an unknown magnitude, namely, the horizontal abutment reaction, is thereby introduced into the foregoing problem, which then becomes indeterminate, *i.e.*, incapable of direct solution ; for, so far as the writer is aware, no means have been devised whereby it is possible to determine the unknown magnitudes of three forces which constitute a portion of an equilibrating system consisting of three or more forces meeting at a point. It is the existence of this horizontal reaction in the case of all bridges or roofs exerting a thrust against their abutments which renders the preparation of designs for such structures both tedious and difficult. In fact, if the magnitude of this reaction were once known, the problem of proportionmg the sectional areas of the several members of an abutting truss such as that represented in Fig. 1 would be comparatively

simple ; and, it is to be hoped that the method for its determination which is now about to be submitted to your notice, and which is analogous to that adopted by Professor Clark Maxwell in dealing with solid web arch rings hinged at the springings, may commend itself to your favourable consideration.

As the term "Modulus of Elasticity" frequently enters into any discussion connected with the determination of stresses in all structures capable of exerting an abutment thrust, it may be well for us, before proceeding further, to direct our attention towards acquiring an accurate perception of its meaning.

It has been ascertained that, within certain limits, the extension of a bar of iron is practically proportional to the intensity of unit stress producing that extension or elongation. Thus, if any bar of iron be extended a certain amount under some particular tensile stress per square inch of sectional area, that extension will become doubled, trebled, &c., according as the stress producing it is doubled, trebled, &c., and, from the existence of this proportionality it necessarily follows that, no matter how many different tensile stresses may be applied to that bar, the ratio obtained from dividing the total elongation by the corresponding stress per square inch of sectional area would be found to possess exactly the same numerical value for each particular unit stress. What is true of the extension of the whole bar must also hold good with respect to the elongation of each particular part of it. Hence, we may say that the elongation of an inch in length of any bar of iron divided by its stress per square inch of sectional area gives a ratio which, within certain limits, is practically of an invariable or constant value, and the numerical value of this constant ratio is termed the "modulus of elasticity" of that class of iron from the behaviour of a specimen of which this constant ratio has been deduced. The different qualities of iron, as well as the greater number of materials used in the construction of engineering and architectural works, have their corresponding moduli of elasticity, which may be found tabulated in Dr. Stoney's book on the theory of stresses, and also in other text books treating of the principles of construction.

Let l be the length (expressed in inches) of a bar of any material whose extensions are subservient to the law of elasticity just referred to ; l' its total elongation (also expressed in inches) when exposed to a total tensile stress S (expressed in tons) ; a, its sectional area (expressed in square inches) ; and E, its modulus of elasticity

(expressed in tons per square inch). Therefore $\frac{l'}{l}$ expresses the elongation of one lineal inch of the bar under a tensile stress per square inch of sectional area, which may be expressed by the ratio $\frac{S}{a}$; and consequently, according to the definition just given.

$$E = \frac{l'}{l} \div \frac{S}{a} = \frac{a \times l'}{S \times l}$$

or

$$l' = \frac{S \times l}{a \times E}$$

Since it is generally assumed that the modulus of elasticity is the same for compression and extension, it follows that the above formula is applicable not only in the case of materials being subjected to the effects of a tensile stress, but also when these materials are exposed to a compressive stress. Hence, assuming that S denotes either a tensile or compressive stress,

$$l' = \frac{S \times l}{a \times E} \qquad (1)$$

in which l' will represent an extension or a compression according as the material is exposed to a tensile or compressive stress, consequently formula 1 enables us to calculate either the elongation or compression of any member of a bridge, for instance, when the length of that member, its sectional area, the magnitude and quality of the stress to which it is exposed, and the modulus of elasticity of the material employed are known quantities.

Determination of Horizontal Thrust.

Figure 1 represents an abutting truss hinged at its springings and supporting a load uniformly distributed per foot run of span. In this figure, as well as in figure 4, each letter (excepting W, v, and h) denotes a space, and each member of the truss diagram is designated by the two adjacent letters. The uniformly distributed load is, for the purposes of calculation, assumed to be concentrated at the points where the diagonals intersect in the outer flange; and, as these concentrated loads or weights W_1, W_2, W_3, etc., will produce corresponding abutment thrusts from the magnitudes of which that of the total thrust may be derived, it is proposed to deal with each of these weights, commencing with W_2, as acting separately and independently.

In figures 1 and 4 (plate 14) the entire space underneath the lower flange is denoted by the letter Z.

Of course the actual thrust against each abutment is exerted in an oblique direction, and it is from the corresponding oblique reactions, one of which is shown at the right abutment in figure 1, that the stresses in the several members of the truss will be ultimately determined; but, for the present, it is more convenient to consider the effects of the vertical and horizontal reactions into which each of those oblique reactions may be resolved.

Let the vertical reactions of W_2 (fig. 4) be denoted by v and v′, the magnitudes of which may be obtained as in the case of an ordinary girder. The effect of v is supposed to be transmitted through the several members of the truss from the left abutment to the point of application of W_2, and that of v′ is considered as being similarly conveyed from the right abutment.

Let the horizontal components of the reactions developed at the left and right abutments by W_2, be respectively denoted by h and h′. These horizontal reactions are obviously equal to each other in magnitude; but, for the sake of uniformity of notation, as well as for the purpose of promoting perspicuity, it is considered desirable that they should be distinguished by appropriate indices.

Let the letter L denote the length of the span; l, the length of any member; a, the sectional area of any member; s, the stress in any member produced by v or v′; s′, the stress in any member produced by h or h′; and S, the resulting stress in any member, being the sum or difference of s and s′.

If the truss were erected as represented in figure 4, so that its extremities would be free to move horizontally, it is manifest that an alteration in the length of any member, G g for instance, would be accompanied by a corresponding alteration in the length of the span; and, assuming every other member to be absolutely rigid for the time being, it is also manifest that this alteration in the length of the span which we shall call L′ must be proportional to the alteration in the length of G g which we shall desingnate l′. From the existence of this proportionality it follows that the ratio $\frac{L'}{l'}$ must possess a constant numerical value which we shall denote by the letter q. Hence

$$\frac{L'}{l'} = q \qquad (2)$$

or $$L' = q \times l'$$

ut by formula 1 $$l' = \frac{S \times l}{a \times E}$$

therefore $$L' = q\frac{S \times l}{a \times E} \qquad (3)$$

in which S is the stress in Gg.

Again, since either half of the truss may be regarded as a bent lever having its fulcrum at the point of intersection of f g and g i, it necessarily follows that the vertical reaction v must be directly proportional to the stress s which it produces in G g : and therefore, the ratio $\frac{s}{v}$ must possess a constant numerical value which we shall denote by the letter p. Hence

$$\frac{s}{v} = p$$

or $$s = v \times p \qquad (4)$$

If this value of s be substituted for S in equation 3, we shall obtain the extension of the span due to the compression produced in G g by the reaction v. Thus

$$\text{Elongation of span} = q\,p\frac{v \times l}{a \times E}$$

By proceeding in a precisely similar manner the extension of the span due to the alteration in length of each member produced by the reaction v or v′ may be obtained : and then, the total extension of the span which would result from the effects of W_2 if the truss were free to move horizontally on its bearings, may be expressed thus :

$$\text{Total extension of span due to } W_2 = \text{sum of } q\,p\frac{v \times l}{a \times E} \qquad (5)$$

But the truss is not erected as represented in fig. 4. It exerts a thrust against each of the abutments which are assumed to be perfectly rigid, and its span cannot become increased in length owing to the horizontal reactions of these abutments, the effects of which we shall now proceed to investigate.

The horizontal reaction h, if acting alone, would produce a tensile stress (s′) in the member Gg, and, owing to either half of the truss acting as a kind of lever, pivoting round the point of intersection of fg and gi, it follows that

s′ is proportional to h

and it has been shown that

L′ is proportional to l′

L′ being the alteration in length of span due to the alteration (l′) of G g, which would be produced by the stress s′

$$\text{therefore } s' : L' :: h : l'$$

$$\text{or } s' : h :: L' : l'$$

$$\text{therefore } \frac{s'}{h} = \frac{L'}{l'}$$

$$\text{but by formula 2 } \frac{L'}{l'} = q$$

$$\text{therefore } \frac{s'}{h} = q$$

$$\text{or } s' = q \times h \qquad (6)$$

On substituting this value for S in formula 3, we obtain the contraction of the span due to the elongation which would be produced in G g by the horizontal thrust h, if acting alone. Thus—

$$\text{Contraction of span} = q^2 \frac{h \times l}{a \times E}$$

and since the stress in each member of the truss due to h or h′ produces a corresponding contraction of the span, it follows that the total contraction of span due to h and h′, if acting alone, would be expressed thus—

$$\text{Total contraction of span due to h and h′} = \text{sum of } q^2 \frac{h \times l}{a \times E} \qquad (7)$$

But, owing to the assumed rigidity of the abutments, the span cannot become altered in length; hence, the extension of it which would be produced by v and v′ must be exactly equal to the contraction of it which would be produced by h and h′.

$$\text{Therefore, sum of } qp \frac{v \times l}{a \times E} = \text{sum of } q \frac{h \times l}{a \times E}$$

$$\text{and, denoting } \frac{l}{a \times E} \text{ by } r$$

$$h = \frac{\text{sum of } q\,p\,v\,r}{\text{sum of } q^2\,r} \qquad (8)$$

On Plate 15 the Greek letter sigma denotes "the sum of"; and the reaction of the right abutment is denoted by v′ and not v as given at the bottom of plate.

In order to apply this formula it is essential that the sectional area (a) of each member of the truss should be known, as would be the case when the problem to be solved consisted in investigating the stability of an existing structure, of which it is convenient, for the present, to consider the truss delineated in fig. 1 as a representation. Once the sectional areas of the several portions of the truss are known the value of r for each member may be readily ascertained, and hence, in order to obtain the magnitude of h with the aid of formula 8, it is only necessary that the values of p and q for each member of the frame should have been previously determined.

If the vertical reaction v be assumed equal to unity in formula 4, we would have

$$s = p$$

that is, the value of the constant ratio p for any member of the truss is identical with the stress which would be produced in that member by a unit vertical reaction, and hence we have the following rule for determining the several values of p :—

Determine the magnitude of the stress produced in each member of the truss by a unit vertical reaction, then these magnitudes numerically express the respective values of the constant ratios due to a vertical system of loading.

Again, if h be assumed equal to unity it follows from formula 6 that

$$s' = q$$

and hence the following rule for determining the several values of q :—

Determine the magnitude of the stress produced in each member of the truss by a unit horizontal reaction, then these magnitudes numerically express the respective values of the constant ratios due to a horizontal abutment reaction.

After having ascertained the values of p and q for each member of the truss, by drawing stress diagrams similar to those represented in figures 5 and 6, which have been respectively constructed for a unit vertical and unit horizontal reaction, a table resembling that headed No. 1 should be made out. Of course if the two halves of a structure were dissimilar, such a table would have to include every member of the frame, but if they are similar, as in the example under notice, those members composing either half need only be tabulated.

When filling up the columns under W_1, W_2, &c., care should be taken to use the proper value of v, namely, the reaction of the left abutment when dealing with a member situated on the left of the point of application of the weight at the head of the column, and the reaction of the right abutment when dealing with a member situated to the right of that point. In the case of both of these reactions being common to the same member, their mean should be tabulated.

Table No. 1 illustrates the mode of procedure which should be adopted in order to obtain the magnitude of the abutment reaction due to one or any number of the weights W_1 W_2 &c., and by compounding this horizontal reaction with the total vertical reaction, the magnitude and direction of the required oblique abutment reaction may be readily determined, Then from this oblique reaction the actual stresses produced in each member of the truss may be derived by constructing a single stress diagram similar to that delineated in Fig. 7, They may also be arrived at by taking the algebraic sum of the stresses which would be induced by the vertical and horizontal reactions considered as acting independently, in which case two stress diagrams, somewhat similar to those shown in Figs. 5 and 6, would have to be constructed.

Table No. 2 shows the theoretical saving of material which would probably be realised by making the truss abutting in place of permitting it to move freely on its bearings.

A more typical form of abutting truss than that delineated in Fig. 1, might easily have been chosen for the purpose of illustrating the method of calculating abutment thrusts set forth in this paper. But the example, to the consideration of which your attention has just been directed, has already been investigated in a most minute and elaborate manner by Professor R. H. Smith ; and it is solely on this account that it has been selected on the present occasion, in order that a comparison might be readily instituted between two widely different modes of procedure, and between the results derived from an application of each of these modes to the solution of one and the same problem. It would, of course, be futile and unreasonable to expect that identical results should follow from these two distinct and dissimilar modes of calculation, because absolute mathematical accuracy is seldom if ever attainable in conducting any of those complex operations which more or less frequently command the thoughtful consideration of those whose avocations lead them to labour in the vast and eminently interesting field of applied mechanics. However, on referring to page 148 of

the 49th volume of the *Engineer*, it will be found that the abutment thrust, as calculated by the gentleman whose name has just been cited, is practically equal in magnitude to that deduced from table No. 1 : and it will also be found that the sectional areas computed in both instances, if not identical, at least exhibit an approximation to being so which should satisfy the desires of even the most fastidiously disposed engineer.

It rarely happens that a person engaged in designing framed engineering structures finds himself called on to inquire into the stability of an existing truss, the sectional areas of whose members are given quantities. On the contrary, the determination of these same sectional areas almost invariably constitute the problems which present themselves for solution in this important branch of engineering. In abutting trusses, these sectional areas, as already remarked, cannot be calculated either directly or with anything approaching to what would be styled mathematical precision ; and in order that they may be determined within a satisfactory degree of approximation by utilising formula 8 or any other similar formula constructed for the purpose of attaining the same end, it is essential that each member of the truss should have been previously assigned some particular sectional area of a probably correct value ; then the accuracy of these assumed values may be tested and the proper ones deduced by proceeding in the following manner :—

Either assume or determine approximately a sectional area for each member of the truss. From these sectional areas and the given system of loading, calculate the horizontal thrust as already described ; and, for the horizontal thrust thus deduced, determine the proper sectional areas which should be assigned to each member of the frame. If these latter areas practically agree with the assumed values, the problem is solved; but. if not, the assumed areas must be modified, and the operation repeated until a satisfactory degree of equality is obtained ; one, or at most two repetitions will generally be found sufficient.

No doubt, the task of designing an abutting truss is, under existing circumstances, both tedious and troublesome ; but the author feels confident that the many advantages possessed by this type of structure when erected under favourable conditions, will result in speedily bringing it into favour with engineers. Precedents will thus be established, tables of weights will be compiled, deformations will be observed and

recorded, and many other valuable statistics shall be rendered available which will tend to materially simplify and facilitate the prosecution of an undertaking that is now fraught with many delays and inconveniences. Even if this important problem were not capable of simplification, the preeminent adaptability of the arch truss to special localities would unquestionably warrant the incurring of whatever additional trouble the process of designing it may entail.

Approximate Determination of Horizontal Thrust.

The truss represented in fig. 8 has been designed to carry a permanent bridge load of 1 ton per foot run of span, and also a moving load of the same intensity. Assuming that the moving load covers the whole span, each of the weights W W_3, etc., would have a magnitude of 20 tons, while W_1 and W_{12} would each have a magnitude of 10 tons. Then if a corresponding line of weights (fig. 9) were set off, and the polar distance (HO) selected so as to represent the horizontal abutment thrust, it is well known that the corresponding polar polygon passing through the extremities of the truss would constitute what is termed the line of pressure or line of equal horizontal thrust. Consequently, if we knew the exact value of the horizontal thrust developed by the given arrangement of loading, we could at once make a faithful delineation of the true line of pressure; or, *vice versa*, if we were enabled to produce a correct representation of the true line of pressure, we could immediately deduce from it the exact value attained by the actual horizontal thrust. But, so long as the magnitude of this horizontal thrust remains undetermined, it is impossible to trace out the corresponding true line of pressure, except in the case of the braced arch where it passes through three fixed points. However, owing to our knowledge of the fact that it tends to coincide with what Moseley has styled the line of least resistance when treating of the solid arch ring, we can, by drawing a line of pressure so as to pass through a point situated near the central bay of the upper flange, approximately ascertain the value of the horizontal thrust; and, from this approximate magnitude, the sectional areas of the several members of the truss may be deduced with sufficient accuracy to render them applicable to being formed the basis on which the more elaborate and exact method previously described may be founded. To obtain this approximate value of the horizontal thrust, the mode of procedure would be as follows:—Draw a vertical line

(PQ) through the centre of gravity of the weights on one-half of the truss : this vertical is the line of action of the resultant of these weights. Select a point in the centre line of the truss and near the central bay of the upper flange. Through this point draw a horizontal line to intersect PQ ; and join this point of intersection (K) with the left extremity (A) of the truss. Set off the line of weights FG (Fig. 9) to represent the load on the whole truss ; through the centre point (H) of FG draw a horizontal line HI ; and through F draw the line FO parallel to AK. Then, the line HO will represent the required approximate value of the horizontal thrust, and from it the corresponding line of pressure may be drawn as shown by the thick dotted lines in figure 8, and the probable sectional area of each member deduced by constructing a stress diagram similar to that shown in figure 7.

The approximate value of the horizontal thrust, obtained in accordance with the method just described, for the truss delineated in figure 1, is shown by the line ZG in figure 2 ; and the line of pressure to which it corresponds is shown by the thick dotted lines on the former figure. The true line of pressure is drawn in thick full lines on figure 1 ; and the correct magnitude of the horizontal thrust, as obtained from table 1, is shown by the line ZG in figure 3. It will be observed that the magnitudes of the horizontal thrust as given by figures 2 and 3, only exhibit a discrepancy to the insignificant amount of 0.5 tons, thus demonstrating the feasibility of obtaining a very close approximation to the correct sectional areas of the members of an abutting truss from a careful application of the method which it is to be hoped has been clearly elucidated in the preceding paragraph. Of course it may happen in some instances that the approximate value of the horizontal thrust, derived from this method, does not agree so closely with its true value ; but by exercising a little judgment, it may always be found with sufficient accuracy to enable us to proceed with operations that lead to more correct results, and to construct a line of pressure capable of affording reliable indications as to whether the truss would be stable or not in its existing form.

However, although the maximum horizontal thrust will be developed when the moving load covers the entire span, still the maximum stress in every member would not be that due to this arrangement of loading. On the contrary, some members are much more severely

strained when the moving load covers only a portion of the span, so that before the probable sectional areas derived from the former disposition of loading be constituted the basis of operations for the prosecution of any elaborate or accurate calculations, they should be slightly modified in a manner about to be explained. For our purpose it will be sufficient to consider the moving load as covering exactly half the span ; and in this particular case, as well as in every other case of unsymmetrical loading, that portion of the line of pressure passing through the vertical axis of symmetry of the truss will not be horizontal, as in the preceding example ; and, in order to construct a line of pressure so as to pass through some particular point in this axis or centre line of truss, as well as through its two extremities resting on the abutments, *i.e.*, through three fixed points, it is necessary to proceed as follows :—

With any pole O′ (Fig. 11) draw the polar polygon shown in Fig. 10, and produce its extreme sides until they intersect. This point of intersection will be situated on the line of action of the resultant of the total load bearing on the truss (see author's paper on graphic statics.) Extend the side passing through the centre line of truss in both directions until it intersects the extreme links of the polygon produced ; and through these latter points of intersection draw the verticals PQ and RS. Take a convenient point (E) in CD, and join it with the points A and B ; also join the points M and L where the lines AE and BE respectively intersect the verticals PQ and RS ; and produce LM to intersect a production of AB in J. Select a point (T) in the centre line of truss through which the true line of pressure would be likely to pass ; and from J draw a line through T to intersect the verticals PQ and RS in the points U and V respectively. Then, if through F and G (Fig. 11) two lines be drawn respectively parallel to AU and BV, they will intersect in a point O, which is the pole of the required line of pressure passing through A, T, and B. The lines OF and OG represent the magnitudes and directions of the oblique abutment thrusts. whilst the horizontal line to FG represents the magnitude of the corresponding horizontal thrust, from either of which thrusts the approximate values of the several members of the truss may be deduced as already explained. In selecting the point T, it is, of course, necessary to exercise some judgment, which may, however, be acquired from a comparatively brief experience in the delineation of these lines of equal horizontal thrust.

By comparing the sectional areas of the various members obtained from this unsymmetrical arrangement of loading with those previously calculated on the supposition that the moving load was uniformly distributed over the entire span, a sufficiently close approximation to the true values of the sectional areas may be arrived at to enable us to proceed, under favourable conditions, with the construction of a table similar to that headed Table No. 1. And, in passing, it may be well to remark that, in compiling such a table, the lengths of the several members of the truss must be obtained as aacurately as possible. Consequently, unless these quantities are determined by calculation, the truss diagram from which they are derived should be drawn to a scale of not less than eight or ten feet to an inch. Also, the stress diagrams, with the aid of which the values of p and q may be advantageously computed, should not be drawn to a scale of less than one or two inches to a ton, and the values of r should be carefully worked out.

The method of drawing a line of pressure through three fixed points which has just been described, is especially applicable to what is termed the braced arch. In dealing with this form of structure it is not necessary to draw the the line of pressure through an assumed point situated near the centre of the span as in the preceding example, for in this particular case the two springing points together with the centre of the hinge connecting the two portions of the arch at the crown, constitute three permanently fixed points through which the true line of pressure must pass, and from it the exact value of the actual horizontal abutment thrust, or of the oblique abutment thrust, may be readily deduced, as already explained in the preceding paragraphs.

In concluding, the author desires to offer some apology for whatever omissions and imperfections his paper may be found to contain. The subject of which it treats, besides being comprehensive and abstruse, is deeply entangled in the closely woven web of mystery with which it has been surrounded by mathematical experts. It would furnish ample matter for the compilation of a fair sized volume, and, at most, only its salient features could be touched on in a paper attaining even to the prolixity of that which has been introduced to your notice this evening. However, a want has long been experienced for the enunciation of some simple method of calculation which would enable ordinary professional practitioners to utilise the

modern form of the "metallic arch," or as it is sometimes styled the "elastic arch." Such a method should be capable of affording, though not necessarily accurate, at least practically correct results. Its application should be independent of the higher branches of mathematics, of which few of those who are busily engaged in the prosecution of a general professional practice can find time for maintaining their knowledge in an exemplary condition of efficiency, and it should be free from any complications that might lead to troublesome or aggravating errors. To give publicity to a mode of determining the proper sectional areas for the several members of an abutting truss that seemingly fulfils these conditions has been the object of the author in preparing the remarks which he has just read for you; and, if his efforts should not prove successful, it is his earnest hope that they may at least pave the way for the labours of more capable and accomplished investigators.

The Paper was illustrated by a number of diagrams, from which plates 14 to 16 have been prepared.

MINUTES OF PROCEEDINGS.

8th JULY, 1886.

Walter Shellshear, President, in the Chair.

THE MANUFACTURE OF ICE BY THE "BETH PROCESS."

By FREDK. T. BAGSHAWE, Assoc. M.I.C.E.

The author proposes in this paper to describe the machinery used in the manufacture of ice by the "Beth Process."

He will first take the liberty of quoting from a paper read before the Institution of Civil Engineers in London, by A. C. Kirk, Mem. Inst. C.E., which deals with the subject and describes a small machine to illustrate the principles.

"The manufacture of ice to supply a large demand is of comparatively modern development.

To the use of ice and cooling chambers we are indebted for the production of our finest candles, for the better production of much of the beer we drink, for the better curing of pork and bacon, and for the better condition of the butcher's meat which we daily consume.

The artificial production of ice has long been a matter of scientific curiosity in Europe.

Older scientific treatises devoted much space to the composition of freezing mixtures, and to descriptions of methods adopted in India for producing thin ice on favourable nights, by exposing water to the combined action of radiation and evaporation, &c.

These processes did not meet the demand, and they do not come within the scope of this paper."

"Of the liquid employed in the manufacture of ice, ether and volatile hydro-carbons are highly efficient when the difference of temperature required is not too great.

With ammonia a very wide range of temperature is practicable, but this liquid possesses a peculiar property by which mechanical compression and exhaustion can be dispensed with, chemical com-

pression (if we may use such a phrase), being substituted. A machine on this principle was proposed by Mr. Careé in 1859. It is based on an experiment of Faraday's.

While experimenting on the liquification of gases under the combined influence of pressure and cold, he placed in one of the branches of a strong U tube of glass a body which, under the influence of heat, gave off a quantity of the gas he wished to liquefy. The other branch he placed in a freezing mixture.

Heat being applied to the end containing a dry chloride of silver, which had absorbed a quantity of ammoniacal gas, while the empty end was kept cool, he found after a little time in that end a liquid which was liquid ammonia.

He then observed that as the tube cooled the ammonia evaporated, and the gas was re-absorbed by the chloride of silver.

Here was a refrigerating machine, for during its evaporation the ammonia must absorb heat.

Ammonia behaves in the same way with chloride of calcium, with charcoal and with water. The two former however are no use for a practicable refrigerating machine, owing to their almost total absence of heat conducting power and their sluggish action, Mr. Carré, by using water, which from the mobility of its particles, and the rapidity with which it could be heated and cooled, produced a practicable machine.

In its simplest form Carré's machine is intermittent in its action, and consists of two strong reservoirs, connected by a pipe, in fact Faraday's U tube enlarged at each end. The larger end is a vessel about three-quarters filled with a strong concentrated solution of ammonia in cold water. When this is heated and the smaller vessel placed in cold water, the ammoniacal vapour is expelled from the water, and, under the influence of cold and pressure is condensed into a liquid in the smaller vessel. The hot water or rather the hot weak ammoniacal solution left in the larger vessel, being now cooled by the application of cold water to the outside, or otherwise, powerfully re-absorbs the ammoniacal vapour as fast as it is generated. Thus the pressure being continually removed by absorption, the liquid ammonia boils in the smaller vessel, and this goes on as rapidly as we can cool the contents of the larger. Water, under the influence of heat and cold, performs the same function as the piston in a machine, promoting

the evaporation of the gas, by creating a vacuum, and also compressing and condensing the gas without the use of any mechanical arrangement. Although no engine in the ordinary sense is employed, energy, in the form of heat, is of necessity consumed, and heat is absorbed at a low temperature and rejected at a higher, as in all other refrigerating machines."

Ammonia gas has a most remarkable property, viz., that water will absorb or dissolve it, for as soon as ever it is brought into contact with water it disappears because the water absorbs it so readily. It is transparent and colourless, and has also a very pungent suffocating smell. Some accurate data on the absorbing power which water has for ammonia gas have been given by Bunson He has shown that one pint of water at 0 °c or the temperature of melting ice will absorb 1180 pints of ammonia gas. This absorbing power, however, is greatly diminished as we increase the temperature. At 20 °c it will only absorb 680 pints, whilst at 40 °c only 444 pints of ammonia gas.

For a very long time no one knew that spirits of salt and spirits of hartshorn were solutions of gases. The celebrated Henry Cavendish when experimenting on hydrogen, attempted to make the gas by acting on spirits of salts with copper. He obtained a gas which seemed to disappear as soon as it came in contact with water. Priestly repeated the experiment and ascertained that copper played no part whatever in the phenomenon, and that a gas might be readily obtained by heating the spirits of salts alone in a flask and catching the gas over mercury. The gas he obtained he called marine acid air. We now name it hydrochloric acid. It seemed to Priestly that spirits of salts was nothing more or less than a solution of this gas in water, and the experiment suggested a new line of inquiry. Might there not be many liquids deriving their peculiar properties from some gas held in solution in this manner? Following out this idea, in one of his experiments he took spirits of hartshorn, treated it, and arranged matters so that if any gas came off it would be caught over mercury. His expectations were realized, and he obtained a gas which he named alkaline air, and this is what we now call ammonia.

"The range of temperature available is great, much greater than in the case of ether, for at the atmospheric pressure, the boiling

temperature of ammonia is 40 deg. Fahrenheit. Usually the pressure required to liquefy the gas is 150 lbs. per square inch. This is the simplest refrigerating machine made, but its intermittent action limits its use.

It, however, is easily transformed into a machine of continuous action, the operation being the same.

But, whereas in the intermittent machine there were two parts, each performing two functions alternately, at a high temperature and at a low one, we must now adopt four parts, each performing one function and kept at one temperature

Messrs. Mignon and Rouart's Paris Machine, Fig. 1.

As made by Messrs. Mignon and Rovart, of Paris, the parts consist of a boiler (A, Fig. 1) in which the ammoniacal gas is distilled from its solution, a condenser (B) to liquefy the gas, a volatiliser or boiler (C) in which the liquid ammonia boils and absorbs heat, and an absorber (D) into which the vapour as it is generated in (C), passes and is absorbed by cold water.

These different parts are connected by: 1st, a pipe "aa" taken from the top of the boiler A to the liquefier B. 2nd, a feed pipe "bb" from the bottom of the liquefier B to the top of the volatiliser C. 3rd, a pipe "cc" taken from the top of the volatiliser C to the absorber D. 4th, a pipe "dd" taken from the bottom of the boiler A to the top of the absorber D. 5th, a tube "ff" taken from the bottom of the absorber D to the top of the boiler A. This apparatus is completed by a pump F in the circuit of the pipe ff from the absorber D to the boiler A, a cock G on the pipe dd, and lastly a cock H in the pipe bb. The operations carrried on in this apparatus are as follows:—

The ammoniacal gas is distilled from its solution in water in the boiler A, under a pressure in ordinary circumstances of about ten atmospheres.

The volatised ammonia passes by the pipe "a a" to the liquefier or condenser B, which is kept cool by a supply of water.

The ammoniacal gas being condensed in the liquefier B, passes by the pipe "b b" to the volatiliser C, in which it boils and abstracts heat.

As the liquefier or condenser B is ordinarily at a pressure of about 10 atmospheres while the volatiliser or boiler is at a pressure of about $1\frac{1}{2}$ atmospheres, the liquefied ammonia would rush at once through the feed pipe "b b" were it not regulated by the cock H so as to maintain at all times some liquefied ammonia in the condenser B.

The ammoniacal gas, as fast as it is formed, passes from the volatiliser C to the absorber D, in which cold water absorbs it, compressing it in fact, and liquefying it, forming a solution of a convenient degree of saturation. This ammoniacal solution is returned to the boiler A and the process is repeated, But in the course of distillation in the boiler, which must be performed quietly and without agitation, the solution of ammonia is found at the bottom to be comparatively poor ; and while the strong solution from the absorber D is returned in the boiler A by the pump F, a corresponding amount of weak solution is drawn from the bottom of the boiler and returned to the absorber. The flow of this water is regulated by the stop cock G. In order to prevent the great waste of heat, which was unavoidable in the intermittent machine, in cooling down the spent, ammoniacal solution to enable it to act as an absorber, an interchanger is introduced, by which the heat of the spent solution, as it escapes from the bottom of the boiler A on its way to the absorber D, is given up to the strong solution on its way from the absorber D to the boiler A.

Having thus described the principles on which ice is made by the circulation of ammonia in a small experimental machine, the author will now describe how those principles are applied to manufacture ice for the market, by a large machine capable of making twenty tons of ice in twenty-four hours.

The works which the author will describe have been erected by the Sydney Ice Co., Limited, and are situated in Harris-street, Pyrmont.

Beth Process.

The process used is known by the name of the "Beth" process, and the principles of the patent consist in the circulation of ammonia through upright coils of pipes which are placed in parallel rows in a freezing chamber.

This ammonia is deprived of its lateut heat under pressure, and on being released into these coils, it absorbs the heat from the water

which is constantly being sprinkled over them by a row of revolving sprinklers interspersed between each row of pipes.

This water gradually freezes, and expanding into the space between the pipes, forms a solid mass of ice 45 ft. long, 2′6″ thick, and 16 ft. high, resting on its base on a concrete floor.

The Works.

The works under consideration in this paper stand on an area of 8000 square ft., and consist of three floors, viz,, a basement, a ground floor, and an upper floor or roof, Fig. 2 and 3.

Basement.

In the basement are the furnaces for the retorts or ammonia boiler.

Ground Floor.

On the ground floor are the engine and pumps, the ammonia retorts, and steam boiler for driving the engine, with the offices and weighbridge while at the back of the building are the stables and van houses.

Upper Floor or Roof.

On the upper floor, which also acts as the roof of the building, are the absorbing coil, condensing coil, and dryer or interchanger. This floor is surrounded by a brick parapet 2ft. 6in. high, with a brick on edge coping and cement weathering. It is formed of $2\frac{1}{2}$in. x 1in. boards, tongued and grooved and well tarred. Over this is placed a layer of felt well tarred, then another floor of $2\frac{1}{2}$in. x 1in. boards tongued and grooved, the whole is then covered with a thick coating of pitch to insure its being watertight.

Well in Floor.

A well is formed in the centre of this floor 2ft. 6in. square. This floor has a fall of about 1 in 50 from the sides to the centre into which all the water from the large sprinkler runs, whose use, will be explained later on.

The walls all through the building are 18in. thick.

Freezing Room.

The freezing room is at the back of the building, and in height equals the basement and the ground floors. It is lighted in the daytime by six airtight skylights in the roof.

Wooden Lining.

A wooden lining extends all around this room, 15in. from the walls, and this space is filled with sawdust, it measures 55ft. wide by 50ft. long. The floor is of concrete, and has a sump hole formed in it for the purpose of collecting all waste water, from whence it is pumped into a tank which is fixed along the party wall that separates the freezing-room from the engine-room. This water is of course perfectly pure, coming straight from the city main, and is simply that which has not been converted into ice.

Landing Platform in Freezing Room.

Here also is the landing platform some 12 feet above the floor, covered with sheet iron, on which is fixed a circular saw bench having four saws, which cut the ice up into whatever sized blocks are required for the market. Access is gained to this room by a door in the basement at the back of the furnace, and a door from the landing platform inside, into a landing platform outside (as per sketch) which is also used to deliver the ice into the waggons. These waggons are backed through the main entrance, which is big enough to admit the largest of them, on to one of Fairbank's weigh tables, capable of weighing 10 tons, up against the delivery platform where they are filled with ice.

The Machinery.

The machinery consists of an inverted vertical single cylinder 6 h.p. engine with an 8 h.p. multitubular boiler.

Two water pumps, which supply the long tank in the freezing room above mentioned, as well as the large sprinkler on the roof.

Two double acting ammonia pumps to lift the ammonia back into the retorts, and a frame containing four circular saws for cutting the ice into any required size.

The author thinks he has now said enough to clearly describe the buildings and machinery, and will now describe the process by which the ice is made. For this purpose he thinks it will be best to trace the course of the ammonia from the time it is put into the retorts until it returns to them.

The Retorts.

It will be necessary first to describe the retorts, which we will suppose are filled with ammonia liquor, and the furnace fires lighted.

On reference to figs. 8 and 9, you will see they are built over three furnaces of fire brick in which coke is burnt, and are arranged in a horizontal coil of six, so that the heat from the furnaces passes under the bottom of each layer of tubes or retorts, on the top of which is laid one course of fire brick set in fire clay.

The retort frame is 15 ft. long by 11 ft. 6 in. wide. At the four corners are placed one cast iron standard, to which are bolted channel iron girders on which the ends of each layer of retorts rest.

The bottom layer of retorts directly over the furnaces are six in number, of 14 in. diameter wrought iron tubes, with a one inch thick flat welded ends, these ends being the same throughout and are used to screw the connecting pipes and bends into. All the other ayers have 12 tubes of 9 in. diameter.

On the top of each layer is placed one course of fire brick set in fire clay, so that although the retorts are round every space is filled, and an airtight flue is formed of the fire brick, coiling backwards and forwards until it terminates in a wrought iron stack in which is placed an ordinary damper to regulate the draught.

The retorts are connected with each other by a piece of pipe accurately threaded at each end, one end is screwed into the retort and the other into a cast iron bend. The last retort in the row is connected to the one above it, and so the coil is completed.

Manifold.

In the front end of each retort is screwed a piece of $\frac{3}{4}$ in. pipe, connected with a 4 in. cast iron manifold, and this again connected into a 4 in. wrought iron pipe, so that this pipe is fed by $66\frac{3}{4}$ in. pipes, one coming from each retort. Each connection is made with a cement composed of litharge and glycerine, which is quick setting and resists the action of the ammonia.

Condensing Coil.

The 4in. pipe leads the ammonia gas generated by heat in the retorts through the roof into the dryer, thence into a 4in. manifold on the top of the condensing coil, which is kept cool by water falling on it from a large revolving sprinkler, where it loses its superfluous heat and becomes a very rich gas; then it passes on through a $1\frac{1}{2}$in. pipe into a coil of $\frac{1}{2}$in. pipe, called the cooling coil (Fig. 12), being now released by a $1\frac{1}{2}$in. valve placed in the engine-room into the top of the freezing plates, and it is around these plates that the ice is made.

The Plates.

These freezing plates are made in a continuous vertical coil 18ft. high of $\frac{3}{4}$in. pipe, each pipe is 12in. from centre to centre, and each plate is 30in. from centre to centre, 18ft. high and long. The ammonia gas now passes through these plates from the $1\frac{1}{2}$in. releasing valve at the velocity of 2000ft. per minute, freezing the water which is falling round the pipes of the plates and manufacturing the ice. (Figs. 10 and 11.)

Small Sprinklers.

The water is distributed over the pipes of the plates by means of fifteen revolving sprinklers screwed into the top of a pipe 45ft. long, as shown in the drawing Fig. 5. They are placed at the top of the plates at 15in. from each one. The revolving T piece has its two ends turned down and terminates in a nozzle; it is prevented from coming off by a set screw working in a slot in the fixed upright piece. They are fixed at irregular intervals on the pipe, but at 15in. from each plate. These pipes are $1\frac{1}{2}$in. in diameter at the entering, and tapering down to $\frac{3}{4}$in. at the other end. The water passing into these pipes causes the sprinklers to revolve and throw the water in a gentle spray all over the surface of the freezing plates, and it is there converted into ice as it falls down. The water is supplied from the long tank above mentioned fixed on to the engine room wall.

All water which is not converted into ice falls on to a concrete floor and thence into a sump hole, whence it is again pumped into the tank. Thus the water supplied from Botany being used over and over again, becomes colder each time, and a great saving is effected. Besides this the ice is far harder and free from flaws than that made by other processes, for, first, all the air is knocked out, and, secondly, the ice is made from the centre outwards.

In each pipe is fixed a tapering strainer made of the finest perforated iron, and these are changed every six hours.

The gas having done its work by making ice on the freezing plates, now passes into a coil called the cooling coil through an arrangement of valves and pipes shown in Figs. 10, 11 and 12, from thence it passes into a 4in. pipe, which leads it up into a flat circular casting fixed on the roof, 2ft. 6in diameter x 4in. deep,

containing 84 holes, Fig. 6 and 7. In this works a flat circular plate covered with small spikes, and it is driven round at about 30 revolutions per minute, by a vertical shaft and bevel gearing worked from the engine-room below; this arrangement is called the agitator, and its use will be next explained, see Fig. 6.

The casing of the agitator has holes in its sides into which are accurately fitted $\frac{3}{4}$in. pipes, which radiate away from it in all directions, like the ribs of an umbrella, and it is called the spider. This spider, which is practically a circular manifold, conducts the gas into the absorbing coil. On one side of it, as shown in the figure, is fitted a 4in. pipe, which brings the gas, as already mentioned, from the freezing-room, conducting it up into the agitator, out of which it passes into the $\frac{3}{4}$in. pipes. A $\frac{3}{4}$in. pipe will also be seen on the top

The use of the agitator is this :—

The gas coming from the freezing-room is still very rich, whilst that in the retorts is comparatively poor, so we therefore bring the poor liquor from them by the $\frac{3}{4}$in. pipe, and this falling on to the top of the revolving plate covered with spikes inside the agitator is completely mixed with that coming from the freezing chambers, and the gas is by this means toned down to the required per centage before entering the absorbing coil. The gas and liquor in returning to the retorts, having been thoroughly well mixed by the agitator, passes through the absorbing coil into another cast iron manifold through which all the gas passes into a 3in. pipe down to the ammonia pumps, and from thence it is forced into the interchanger or dryer.

Fig. 4 is a sketch of the dryer. In it are fixed a number of baffle plates; the gas coming from the pumps on its way down is mixed with the hot gas coming from the retorts by the baffle plates as shown, and when it reaches the bottom it passes through a $2\frac{1}{2}$in. pipe back into the retorts, where it is prepared again to circulate through the machinery.

On the top of the interchanger will be noticed a pipe. It goes to the freezing-room and is used to pass hot gas through any plates that are fully charged with ice, to thaw it off and allow it to be readily taken away without damaging the coil.

Large Sprinkler.

On the roof and close to the agitator is fixed the large sprinkler whose object is to throw water onto the condensing and absorbing coil to aid the liquefaction of the gases on which the economical working of the machine depends. It is shown in Fig. 6 and is constructed as follows. A cast iron pipe revolves on a piece of lignum vitæ at the bottom of a base very much like the trunnion of an oscillating engine, except that it is vertical instead of horizontal. A connection is made in one side of it with number 2 water pump. The whole is surmounted by a casting which has two arms screwed into it of 2in. pipe, terminating in 10ft. of 1½in. pipe perforated with holes and stopped at the outer end. On the bottom is keyed a pinion wheel, and on the same shaft which works the agitator is keyed a worm wheel which working with the pinion wheel causes the whole to revolve and sprinkle water all over the abovenamed coils.

The water falls on the roof and runs into the small well whence it is pumped back again.

Thus we see whether with water or ammoniacal liquor there is no waste if we except the evaporation, which in hot weather is very large, and the leakage which is sure to take place when there are such a vast number of joints, for the author may mention in conclusion that there are in the whole manufactory no less than 25 miles of pipes, and all connected at every 15ft. in the condensing and absorbing coils, and 16ft. in the freezing-room. The author will here take the opportunity of thanking Mr. Sprodd, the late engineer in charge, for the valuable assistance he has given him in preparing this paper.

The paper was accompanied by several diagrams, from which plates 17 to 19 have been prepared.

MINUTES OF PROCEEDINGS,

12th AUGUST, 1886.

Walter Shellshear, President, in the chair.

The following candidates were balloted for and duly elected:—

Member:
HY. T. VALE.

Student:
ROBT. G. EDGELL.

Alteration of Section V., Clause I., of Rules and By-Laws.

Mr. Key, for Mr. Cruickshank, moved that the annual subscriptions for members be two guineas, instead of one guinea, to take effect from October 1st, 1886; making Section V., Clause I., read—"Each member shall pay two guineas, each associate two guineas, and each student one half-guinea per annum."

Seconded by Mr. Mountain, and carried unanimously.

The following paper was then read:—

ECONOMY IN STEAM NAVIGATION,

By WM. S. BAILEY.

Everyone connected with shipping is aware of the keen and increasing competition between the different steam companies, especially on our own coast. Such being the case, any possible improvement which can be made, either by reducing the working expenses or by the employment of superior machinery, must prove of interest at the present time.

Frequently a steamer does well and realizes a fair amount of profit while kept running; but the long and frequent periods of idleness, which become necessary to keep her in repair, cause such heavy expenses as to eat up the whole of the previous profits.

In this paper some of the causes will be mentioned which have struck the author as usually producing these expenses and interruptions. The delay necessary to repair a steamer proves especially hurtful to a small company, having few boats, and in which a boat must be chartered to take the place of the one laid up.

As a general rule the most fruitful sources of expense in steamers are the engines and boilers. The hull usually costs little

for repairs if kept clean and painted thoroughly inside and outside, before rust and scale have commenced to form. The bilges should also be properly cemented, and care taken to replace any cement which may have been removed either by accident or otherwise.

The spars and running gear in a full-powered steamer are, of course, a secondary consideration, and as day by day machinery becomes more improved and reliable, the tendency is to spar steamers even more lightly than has hitherto been done.

It is questionable whether the fitting of sails to steamers is of any real benefit so far as speed is concerned.

Although the speed is undoubtedly increased when sails are used with a fair wind, still the opposite result takes place in even a more marked manner by the influence of a head wind acting on the surfaces exposed to it by the masts, yards and cordage. And this resistance will increase in proportion to the speed at which the vessel is driven.

Sails are usually looked upon more as a means of safety or convenience to the vessel in the event of her engines becoming disabled. The sails and running gear should therefore not be neglected as is too often done, but must be kept in an efficient state of repair, and in such a condition that they may be depended upon at any moment.

Spars are also necessary in steamers to steady them to a certain extent, and their use for this purpose must remain a necessity as long as hulls are built of the present form.

So far as the form of the hull is concerned, the following are the primary considerations which influence the design, namely :—

Speed.
Passenger accommodation.
Carrying capacity.
Handiness in steering.

And that the vessel may be dry and steady in a sea-way—in other words may be a good sea-boat—the proportions which these various conditions bear to each other will vary according to the trade for which the vessel is intended.

For instance, if it be desired to run an ocean trade where great competition exists and in which numbers of people are travelling to and fro, then speed, together with roomy and elegant cabins, becomes an absolute necessity, and must form the chief consideration.

In such a case the carrying capacity will be comparatively low. The ratio of length to beam being greater, the vessel will not answer her helm so quickly, and, as a rule, will pitch more in a sea, owing to the increased fineness of her lines fore and aft.

If on the other hand the vessel be intended for coasting purposes where good inducement is offered for general cargo, then a fair rate of speed, combined with good carrying capacity, will be found most desirable.

If rivers or bars exist the draught of water will also require to be as small as possible.

In this case the proportion of beam to length being greater, the vessel will answer her helm better, and be more easily handled in a river. She will also be drier and steadier in a sea-way, having a better bearing fore and aft.

A decided improvement has lately taken place by the introduction of triple expansion engines in place of the usual two cylinder compounds. Just in the same way as the old low pressure engines were susperseded by the compound principle with steam of 60 lbs., so the introduction of triple expansion marks another era in the history of the marine steam engine.

By the use of these engines, working at a boiler pressure of 120 to 160 lbs. per square inch, the consumption of fuel has been reduced about 20 per cent.

Simultaneously, with the introduction of these engines, we notice the more general use of mild steel for boiler making, and indeed it is chiefly by the substitution of steel for iron in boilers that the high pres ures necessary to obtain this increase of economy are rendered practicable.

Fox's corrugated furnaces are also being generally adopted in place of the ordinary plane ones, experiment having proved them to be twice as strong as plane ones to resist collapsing strain. While acting to a great extent as stays to the boiler ends, they also accommodate themselves to any alteration of form of the boiler due to unequal contraction and expansion; each corrugation acting in the same way as a flexible joint.

The advantages of this triple arrangement of marine engines appear to be,—

1st. Greater economy of fuel owing to increased expansion.

2nd. The cylinders do not require to be so large in proportion to the power developed as they would be if there were only two. More reliable castings are therefore obtained, and the working parts, such as connecting rods, piston rods, valve spindles, top and bottom end brasses, etc., being lighter, are more readily overhauled when necessary for repairs.

3rd. There being three cranks, the crank pin circle may be divided into equal parts, so that the shafting is not subject to such irregular strains as it is when two cranks only are used. For the same reason the engines are much more easily started and reversed, and may be run at a less number of revolutions per minute than is possible with the ordinary two cylinder arrangement. The weight also of the whole structure being more evenly balanced, less trouble is experienced from racing in a heavy sea.

It is also found that the main bearings in these engines, and indeed all the working parts, wear more equally, and give less trouble. This result is no doubt due to the equality of motion imparted by the three cranks.

* * * * *

In estimating the economy of marine engines, it must be remembered that, as a rule, increased economy is attended by increased weight. Take for instance the S.S. City of Melbourne, whose engines are of the ordinary compound type, of thirty-six inches stroke, and fitted with an independent expansion gear. When driving full speed with Brisbane coal, she burned four pounds per I.H.P. per hour, the expansion valve then cutting off at twenty-six inches. When the expansion cut-off was altered to six inches, the consumption was reduced to less than two pounds per I.H.P. per hour, the power of the engines being also of course much decreased by the alteration in the cut-off. It is therefore evident that when this ship is working at her most economical point, the weight of her machinery is greater in proportion to the power given out than it is when she is driven full speed.

On the other hand, as the weight of a ship's machinery forms a large proportion of her total load, it may pay an owner to drive his vessel full speed, and get as much power as possible out of the weight of machinery in her; although by so doing more coal per horse power may be consumed. Economy of fuel may be attained in compound engines by making the cylinders large, and cutting off at an early part of the stroke, but this economy does not always pay for the increased weight of the engines.

This is probably one reason why so many compound engines of recent construction have no expansion gear, cut off with the slide valve alone. There has also been a constant tendency to increase the boiler pressure; so that whereas sixty pounds was at one time considered high, it is now a common thing to supply two cylinder compound engines with steam of ninety pounds per square inch. Under these circumstances a high degree of economy cannot be expected, but, as before explained, the engines and boilers are lighter, and take up less room in proportion to the power indicated; besides costing less money to build than would be the case if economy of fuel only was considered. Cases sometimes occur in which it becomes necessary to sacrifice economy to lightness of machinery, as for instance in torpedo boats, or in light draught river steamers.

At this point attention might be drawn to the saving which is effected by those coasting steamers whose engines are fitted with an independent expansion gear. In our coasting trade it is often necessary to reduce a steamer's speed to four or five miles an hour, so that her time of arrival may suit the tide at the port to which she is bound, or perhaps she is obliged to run at such a speed all night to enter the harbour at daylight, as it may not be safe or convenient to do so during the night. This is especially the case with those boats running through Torres Straits, and those engaged in the northern trade. These vessels have often to reduce their speed during the night, and when no expansion gear is fitted, are compelled either to lower the boiler pressure, or slow the engines by closing the throttle valve, or to link up by putting the wheel back a turn or two. These expedients are all undesirable, and opposed to economical working. But when expansion gear is fitted a good opportunity is afforded of saving coal, which saving may subsequently become of importance in the event of head winds or

accident. In cases where steamers have to make long coasting voyages, every opportunity should be taken advantage of to save coal, as a much higher price must be paid for it at the coaling stations, than is charged in Sydney or Brisbane. In ordinary working also, opportunities often occur for saving more fuel if expansion gear is fitted, as for example when running before a strong fair wind, a slight alteration of the expansion valve will effect a saving in coal without diminishing the ship's speed to any great extent. It sometimes may be desirable to dispense with expansion gear. A ship's speed may be increased by removing the gear, if the boilers are able to supply the additional steam required. Should the boilers not be well able to do this, it will be better not to make the cut-off too late. The best speed is got out of compound engines when the expansion cut-off is just early enough to enable the full boiler pressure to be maintained. It is a mistake to work with so late a cut-off as to lower the boiler pressure.

One of the worst features in the construction of the usual type of compound engines is the arrangement of the valve gear. This generally consists of common slide valves, actuated by eccentrics keyed on the crank shaft, and connected by means of rods to the well known radial link. Valve gear fitted in this way is a constant source of trouble and expense when a high boiler pressure is carried. It may be often observed, that although the low-pressed link motion will run for twelve months or more without repair, the high pressed gear wears slack in a very short time, owing to the pressure of steam upon the back of the high pressed slide valve and forcing it against the cylinder face. So-called improvements are also introduced in the construction of the link motion, by which the bearing surfaces of the link blocks and pins are made ridiculously small in proportion to the weight upon them, and the gear so complicated as to cost a great deal of time and money to repair.

With moderate pressures of steam these defects were not so noticeable, but as the working pressure became higher, the evil so increased, that various expedients have been adopted to relieve the gear of the great strain thrown upon it by the friction of the valve against the cylinder face.

Piston valves have now to a great extent taken the place of common slides for marine engines, and they appear to answer very well. As they work with an equal pressure of steam on each side

they are held almost in equilibrium, the only strain on the valve motion and eccentrics being the weight of the gear itself. These valves also cost less for repair, as all the work may be turned out finished from the lathe.

Another very ingenious method is that adopted by Messrs. Key in the steamers built by them. The slide is here made to work between two cast iron cheeks projecting from the cylinder face, and bolted to it, and in which the steam ports are formed. The slide is thus enabled to work almost free from friction, the pressure on each side being equal.

This form of slide has not only stood the test of practice but has given excellent results. In several vessels well known on this coast, these slides are fitted, and have given the greatest satisfaction. Not only do the eccentric straps run perfectly cool, but each time the covers are taken off, the slides are found steam tight, and the faces both of valves and cheeks showing a first-class surface. It may also be seen that should it become necessary to true up the cheek faces, this may be readily done by removing the cheeks and planing them in the machine, instead of the tedious and expensive method of chipping and filing which is usually practiced when the face forms part of the cylinder itself.

The weight and size of the valve in this arrangement is also much less than that of a common slide.

* * * * *

It is often the practice when comparing the results in economy obtained from different engines, to leave the boiler out of the question altogether; whereas in many cases in which the results are not so good as expected, the boiler power will be found deficient.

For example, in one of our coasting steamers burning Brisbane coal, it was found that when steaming easily, say eight knots an hour, the weight of ashes from the fires formed seven per cent. weight of coal burned; but that when driving full speed (twelve and a half knots) the per centage of ashes and clinker was as much as twenty per cent., thus showing how much of the useful ingredients of the coal is wasted by forcing the fires. So that when a comparison is made between two engines the boilers should always be taken into consideration. Thus, if the results obtained from two sets of engines be compared, and in one instance the boilers be made large

enough, and in the other case too small, the worse result will probably be obtained from those engines supplied by the small boiler, although the engines themselves may be really superior to the others in point of economy.

The importance of having boilers made sufficiently large cannot be overrated, and most of our colonial steamers lose far more by insufficient boiler power than in any other way.

This subject seldom appears to receive the attention it deserves. Attempts at economy appear always to be directed to the engines, while the boilers were by far the greater amount of waste takes place are comparatively neglected.

Perhaps this deficiency of boiler power in our colonial steamers is due to the inferiority of our coal as compared with that obtained in Britain; but, however this may be, it is certain that much needless waste takes place through this cause.

Although boilers may give every satisfaction on a trial trip when everything was in first-class order, the tubes and heating surfaces clean and free from scale and soot, it is a very different thing to get steam from the same boilers when the ship has been even 24 hours at sea, and the fires and tubes have become dirty.

Before having been six months out of dock it may be safely stated that it is not an uncommon thing for our coasting steamers to lose a knot an hour in speed through this cause alone; no allowance having been made when designing the boilers for accumulation of scale on the heating surfaces, dirty fires and tubes, inferior coal, for leaks in the boilers, or for engines passing steam by leaking slides, pistons, &c.

It is the usual practice on this coast to clean two fires out of every eight each watch; that is, in a vessel of say 200 nominal horse power having eight fires, two of those fires are drawn completely out every four hours.

This practice is rendered necessary by the accumulation of ash and clinker in the fires, and which can only be got rid of in this way. The ship's speed is of course reduced while the fires are being drawn and made up again.

Two fires out of eight is the usual practice.

In one case within the writer's knowledge four fires out of eight are cleaned every four hours. That is to say, the boilers are so deficient in steaming power, that half the total number of furnaces

must be drawn each watch, the cold air meanwhile impinging on the surface plates, combustion chambers and tubes, while the adjacent fires are at the same time worked to their greatest power, to make up, as far as possible, for the loss of heat sustained by drawing their neighbours. The unequal strain thrown on the metal of the boilers by this action is apparent, to say nothing of the shameful waste of fuel, caused by throwing overboard every watch so much useful coal as is contained in four furnaces in active combustion. Under such circumstances as these, it is absurd to expect economy.

On the other hand, where the boilers are made of ample power, the following advantages are gained :—

1st. A considerable decrease in the consumption of fuel, as the fires do not require to be cleaned so often. They do not require so much forcing, so that the coal consumed is better used up instead of being wasted through the bars and out of the funnel, as is done by constantly working the fires. A cheaper quality of coal may also be used, thereby affecting a saving; and the furnace doors not being opened so frequently, less heat is wasted in this direction.

2nd. The boilers not being subject to such sudden and unequal strains are less liable to leaks and cracks, and the heating surfaces and uptakes will not be so rapidly burnt away. The boilers, therefore, last a great deal longer, work more satisfactorily, and cost less for repairs. As a rule, too, a better quality of steam will be supplied to the engines, and having always a good command of it, no necessity will arise for easing them at any time, but they may always be worked to the full extent of their power, thus ensuring quicker and more regular passages.

The internal construction of boilers should also be such as to give ample room for men to work in removing scale from the tubes and backs of the combustion chamber, and from between the furnaces. By making marine boilers in this way, not only is the expense of scaling them from time to time lessened, but a better circulation is obtained, and a better quality of steam is supplied to the engines, the water having less tendency to lift and find its way into the steam pipe.

For the same reason a fair amount of space should be left between the tubes, it not being an uncommon thing to find these spaces so blocked up with scale as to defy all efforts at removal.

Also, if the tubes themselves be made large in diameter they will last longer, less difficulty being experienced in keeping them clean and free from salt in the event of leakage.

Where small tubes are fitted to marine boilers, numbers of them frequently become choked up, thereby reducing the heating surface and efficiency of the boiler, and defeating the very object which led to their adoption.

Another cause of expense and trouble is the practice of fitting marine boilers with what are known as wet uptakes. In this arrangement the uptake itself, which is made circular in form, is carried up from the front of the boiler to the funnel in the usual way, and strengthened by angle irons rivetted round its outside surface. Round this again the superheater is built, it being also circular in form, closed at the top but open to the boiler at the bottom, so that the steam entering the annular space absorbs a great deal of the waste heat ascending from the fires, before it is allowed to pass to the engines.

The disadvantages of this form of uptake are that it adds greatly to the weight and cost of the boilers at first, and is troublesome to keep clean, but the chief objection to it is the rapidity with which the angle irons and surfaces of the uptake are destroyed by the action of the steam on one side, and by that of the fire on the other, and the consequent repairs and expense which after a time become necessary; also, the danger of explosion by collapse of the uptake, it being subject to the same collapsing strain as that of an ordinary furnace tube.

It is surprising how quickly the angle irons are eaten away by the steam impinging upon them in its passage, and as the inner surface of the uptake is also exposed to the action of the fires, the amount of wear is doubled, so that one set of boilers will usually last out two sets of superheaters when fitted in this way. Accidents have also frequently occurred by the uptakes collapsing.

A much better and safer plan is to make the superheater in the form of an ordinary drum or dome, and to place it between the uptakes. By this means the total weight and first cost are lessened, all the parts are easily kept clean, and will last as long as the boiler itself, there being little corrosion going on. There is also no risk of collapse.

Of course, by using the first mentioned kind of superheater the steam is heated to a greater degree, and the waste heat is better used up, but the extra expense and risk involved far exceed any advantage gained in this way.

The second method, namely, that of making the superheater in the form of a drum separate from the rest of the boiler is found in practice to be much better; indeed if the steam pipe be of ordinary length and well lagged, little advantage is gained by carrying superheating to a great extent.

In some instances much injury has been done to slides and cylinder faces, pistons and packing, by using highly superheated steam, and which has been too dry. In the ordinary way of working a quantity of moisture is constantly passing through the engines along with the steam, and may be seen running down the rods when the glands are slack.

There is no doubt that in most marine boilers a kind of slight priming is continually going on, the moisture from which acts as a lubricant to the internal working parts, and preserves the surfaces to a great extent. Of course this moisture in the cylinders may result from condensation of the steam after it leaves the boiler, as, for instance, from the use of long and unprotected steam pipes, and although theoretically speaking any water passing through with the steam is a source of loss, still a slight amount of moisture in the steam is most beneficial to the smooth working of the engines, and where the steam-pipe is of a reasonable length, and protected by felt, the steam is super-heated quite sufficiently by placing the superheater in the uptake as described.

When the steam is moist and care taken to keep the packing glands properly adjusted, the valve spindles and piston rods will run without any other lubricant than that contained in the steam itself. The practice of swabbing the rods may therefore be done away with, so that oil is saved and the engine-room and bilges kept clean.

* * * * *

It was at one time the custom to inject quantities of oil or tallow into cylinders and boilers, but this practice is now rapidly dying out, experience having proved that it is not only wasteful, but injurious to the metal, and that it also chokes up the boilers, cylinders, and condenser with grease, impairing their efficiency, and increasing the cost of cleaning and repairs.

With regard to steam jackets, there can be no doubt that a certain degree of economy attends their use, especially when the steam has not been superheated before reaching the engines, as the extra amount of heat contained in the steam around the cylinders tends to retard the cooling of the steam inside the cylinders during expansion and exhaustion.

By this theory of the steam jacket it will be seen that its object is almost the same as that of the superheater, namely, by imparting a greater amount of heat to the steam than that due to its actual pressure, to make up for any loss it may undergo from radiation of heat, either external or internal.

In many steamers where steam jackets are fitted they are not used at all while the engines are running. But although the benefit derived from them may be small when superheaters are fitted, still all marine engines of large size should be jacketted round the cylinders, for the purpose of warming them up previous to starting. By letting steam into the jackets before starting, the whole metal of the cylinders is warmed up gradually and equally, so that there is no danger when starting the engines of cracking the cylinders by unequal expansion.

Cylinders have sometimes been cracked by carelessness in this respect, the throttle valve having been opened while the engines were cold, thus causing an unequal strain on the metal by suddenly raising one part to a high temperature before the heat had time to penetrate the whole mass.

* * * * *

Comparatively few of our steamers are fitted with dampers to their funnels, by means of which the generation of steam may be checked when entering or leaving port.

Most coasting steamers are continually in and out of port.

Those engaged in carrying mails have often to run to a given point off a port, drop anchor while mails, pasgengers, &c., are exchanged, and then proceed on their voyage. As these vessels have usually all they can do to maintain their contract time, not a minute can afford to be wasted, and it is desirable to maintain full speed as nearly as possible to the point of stoppage, and to be able to start at full speed again as soon as the order is given.

When no damper is fitted it becomes necessary on stopping the engines to open all the furnace and tube doors, which practice is very detrimental, as it allows the cold air to come suddenly in contact with the heated internal surfaces of the boilers; but when a damper is fitted the fires may often be efficiently checked without opening the tube doors, the fires are therefore in better order for getting away again, and a saving in time is effected.

In a river, too, or when approaching or leaving a wharf, where the engines are often slowed suddenly, it is very convenient to be able to regulate the fires from the engine room by means of the damper, instead of the usual practice of continually opening and shutting the furnace doors.

. . . . .

Most engineers after having filled their boilers with fresh water are very careful to keep it fresh by blowing off as little as possible at the safety valves. In coasting steamers, which blow their boilers down once a fortnight, or once a month, the water may with care be kept comparatively fresh at the end of that period. Although the scale thus formed is very thin, yet it is much harder than it would be had the boiler been worked at a greater degree of saltness. This hard scale is very difficult of removal, so that when the vessel is laid up more expense is often incurred in scaling the boilers than would be the case had they been worked at a greater density. Indeed the deposit formed by water of from 8 to 10 ounces gives little trouble to remove, and generally falls away itself in flakes from the furnace crowns. The scale-forming properties of fresh water appear to vary greatly in different districts, and care should therefore be taken to note the quality of the scale forming on the plates before working the boilers too fresh. It is a remarkable fact that the thickness of scale which may be allowed, say upon a furnace crown, must be decreased with high pressures. That is to say, that a certain thick ness of scale with a working pressure of 60 lbs. might be quite capable of conducting the heat to the water, but if the same thickness of scale existed with a boiler working at 160 lbs. it would be sufficient to bring down the furnace crowns by allowing the plates to become overheated. This is the reason why triple expansion engines whose boilers always carry a high pressure, usually take their supplementary feed from a fresh water tank instead of from the sea, as is commonly done.

. . . .

Where vessels of light draught were required, and narrow rivers were to be navigated, twin screws have been fitted, it being thought that they would then draw less water, and possess greater facilties for rounding sharp bends. But it is found in practice that twin screw vessels as a rule draw as much water as those fitted with single screws; and although they are undoubtedly more readily handled in a river, the advantage is trifling when compared with the increase in their working expenses.

When steamers are fitted with twin screws worked by two independent sets of engines, the first cost is considerably increased.

More coal is burned in proportion to the power developed; and the number of working parts being doubled, the amount of oil and stores used is greater.

The engines are also more liable to accident; require more attention; and additional work is necessary to keep them in repair.

Also, the brackets and outer bearings for carrying the propeller shafts offer obstructsons which greatly increase the resistance to the vessel's progress through the water.

The propellers themselves being small in diameter, cannot be so well proportioned, as would be the case were one screw of large diameter used. In single screw vessels also, the sides of the engine-room may be utilized for bunkers, or for other purposes, thus economising space, but with twin screw vessels this cannot be done, as the full width of the ship is necessary to accommodate the engines. Vessels fitted in this way are therefore seldom a success, so far as economy is concerned.

It is an argument frequently urged in favour of twin screw vessels, that they are not likely to become totally disabled; as if one engine broke down, the other one would still be able to keep the vessel going. Even admitting this to be the case, the advantage is practically of little importance, especially in a coasting trade, but, inasmuch as there are two sets of engines instead of one, the risk of a break down is doubled.

Twin screw ships have also a bad habit of carrying away their propeller blades, as being placed so near the sides of the vessel, they are very liable to be broken against wharves or other impediments. In this respect they compare unfavourably with the single screw, which from its protected situation is not at all liable to be broken.

* * * *

Of the various designs of compound marine engines, the most common is that in which the cylinders being inverted, the condenser is situated behind them, and the air, circulating, feed, and bilge pumps placed at the back of the condenser, worked by levers extending over the top of the condenser, and attached to the pumps at one end, and to the engine crossheads at the other, by means of the usual links and brasses.

Perhaps a better arrangement is that adopted in the A.S.N. Co.'s steamer, "Tenterden," engined by the North Marine Engineering Company, of Sunderland.

In this vessel all the pumps are worked directly from the crossheads by means of a single straight bar on each engine, and to the ends of which the pump rods are attached, without any intermediate links whatever. The condenser is placed horizontally below the sole plate, and is so arranged as to be quite as accessible and easily overhauled as when placed in the ordinary way. The engine-room above is therefore kept perfectly free of condenser, pumps, links, and levers; and is consequently very easily kept clean.

By working the pumps from the crossheads in this way twenty pairs of brasses, with their links and pins are done away with. The work necessary to keep them in repair is therefore done away with; much less oil is used to run the engines; they are lighter, and cost less for repairs. Their first cost is also lessened, as there are not so many working parts.

The arrangement altogether is a very neat one. The engines work very quietly, give no trouble, are not liable to accident, and prove most economical.

* * * *

One of the chief difficulties in connection with the new triple expansion engines appears to be that of obtaining a good and suitable valve motion. In these engines the piston valves are usually placed at the sides of the cylinders, for if arranged between the cylinders in the usual way, the length of the engines overall would become excesssive.

Owing to this position of the valves, the ordinary link motion is not so well adapted for working them; and many efforts have been made to supersede this expensive and somewhat complicated valve gear.

The triple expansion engines of the White Star Liner "Australasian," are fitted with a valve motion which is a modification of "Gooch's fixed link," the valves receiving their motion partly from the connecting rods, and partly from the pump levers.

In locomotives, Joy's valve gear is now much used instead of the link motion, and appears to work very well.

This gear consists of rods worked from the engine crossheads, attached to a block which slides upon a reversing link placed in front of the engines.

The principal advantage of Joy's valve gear over the link motion for marine engines is, that by its use the crank shaft is left perfectly free of eccentrics and straps, so that the main bearings may be increased in length.

In other respects it is not so well adapted for inverted marine engines as for locomotives.

This arises from the fact that in a locomotive the reversing link is held vertically, so that there is no weight upon it beyond that due to the friction of the valve. But in a marine engine as the link must be placed in a horizontal or at least diagonal position, the whole weight of valve, valve spindle, and valve connecting rod comes upon it.

The weight of these parts in a large marine engine is considerable, and added to the friction of the valve itself is sufficient to cause excessive wear at this part.

The triple expansion engines of the steamers "Coorangamite" and "Burrumbeet," of Huddart Parker and Co.'s line, are fitted with Joy's valve gear. As applied to these vessels the gear possesses as many working parts as an ordinary link motion, and gives some trouble to keep in order. The link blocks especially wear away very quickly from the excessive friction caused by the weight upon them.

On the last visit of the "Aberdeen" to this port, the writer took an opportunity to visit her and ascertain a few particulars as to the working of her machinery. She is a vessel of 362′ in length, with a beam of 44′ 4″, and a gross register of 3616 tons.

Her triple expansion engines are by Robert Napier and Sons, built in 1882, the cylinders being 30, 45, and 70 inches in diameter, respectively; the stroke 54″; and the working pressure 120 lb.

Under these conditions the engines indicate at sea 1900 horse power. The consumption per day of Welsh coal is 37 tons, and of colonial southern coal, 41 tons. These figures, which are well within the mark, give a result of 1·8 lbs. per I.H.P. per hour for the Welsh coal, and of 2 lbs. per I.H.P. per hour for the colonial coal; thus showing a decided improvement on the results obtained from average compound engines, which under the same conditions burn from 2 to 2½ lbs. per I.H.P. per hour. This vessel is fitted with piston valves placed behind the cylinders, and worked by the usual link motion.

* * * * *

Considerable expense is often caused in steamers by the necessity which exists for lifting the crank-shaft from time to time, for the purpose of lining up the bottom brasses. This is caused by the shaft wearing down either at one end or the other from the strain not being equally distributed fore and aft on the main bearings; and also from the brasses themselves wearing quickly away owing to deficiency of bearing surface. This unequal strain is sometimes the result of a heavy wheel for the turning gear being keyed on the shaft, either at forrard or after end, and by its weight adding considerably to the strain upon the adjacent bearing. Whenever a wheel of this kind is fitted, either the bearing next it should be increased in length, or else the wheel itself be made so that it can be disconnected from the shaft when the engines are in motion, which might be easily done.

The main bearings at either side of the cranks should also be placed as close up to them as possible, so as to allow no room for leverage to be exerted by the cranks in bending the shaft. A crank shaft has very little strength to resist a bending strain, on account of the gaps made in it by forming the cranks, and it is therefore important that the strain should be taken close up to the crank cheeks.

The shaft should also be in line, so that all the main bearing brasses may embrace it as closely as possible.

By this means, less play being allowed in the bearings, the shaft has a better chance of withstanding any sudden or undue strain which may be brought upon it. In most marine engines the main bearings are deficient in surface and wear down very quickly, the result being that in a short time the whole engine is thrown out of

line. There is no doubt that when a crank shaft is properly in line, with the brasses fitted in such a way as to take up the strain during the whole stroke without shake, that the shaft is not so likely to break as it is when working out of line. When out of truth, the brasses must be left slack so that the shaft is constantly being sprung backwards and forwards at every stroke of the engine.

A good illustration of the advantages of bearing surface and truth of construction is afforded by a set of triple expansion engines built for the s.s. Enfield, by the Central Marine Engineering Company, West Hartlepool, and for the account of which we are indebted to the *Engineer*.

The cylinders of these engines are 21, 35, and 57 inches diam., respectively, and 39 inches stroke, with a working boiler pressure of 160 lbs. per square inch. The main bearings have much more surface than usual, the two inner ones being two and a half diameters in length, and extending from crank-cheek to crank-cheek. These bearings are so arranged that the bottom brasses may be removed for lining up or renewing without lifting the shaft. The centres of the cylinders are all the same distance apart, so that the crank shaft of any engine will fit any other. The shaft itself is a built one, the pieces being shrunk together, and the crank pins are forged from hollow ingots of steel.

In order to ensure truth in the construction of these engines, the builders first constructed a level erecting table on the floor of the shop, and the sole plate of the engines having been planed underneath, it was bolted to the table and was not again disturbed until the engines were completely finished. The main bearings were bored out and faced down the sides by a steel cotter-bar 27 feet long and $8\frac{1}{2}$ inches diameter.

The engines, after being completed, were moved by steam before being removed from the table, the steam being taken from the shop boilers, and the injection water from the dock alongside. This plan of finishing the engines and steaming them upon a table in the shop has proved so successful that the firm intend increasing the length of their table to 150 feet, so that several sets of engines may be erected upon it at the same time.

The cylinders in these engines are cast separately and joined together by faced joints, which, however, are not steam joints. The valves are all piston valves arranged behind the cylinders and placed

as closely as possible to them, so as to lessen the lengths of the steam ports. The cylinders and valve chambers are all fitted with hard cast iron liners fitted steam tight, the liners in the cylinders forming steam jackets completely round them. The valve spindles, valve rods, and reversing rods, are all of forged steel, and all the valve gear brasses are of phosphor bronze. The stern bush is of brass lined with "lignum vitæ" strips, the length of the bearing part being 54 inches. The Enfield, herself, is 275 feet long by 37 feet 2 inches beam, and 20 feet 6 inches mean draught. When the trial runs were made she had on board over 2800 tons of coal, the ship's total displacement being 4340 tons.

Six runs were made over the measured mile, the mean speed obtained being 10·6 knots per hour. The midship area immersed was 685 square feet, and the speed co-efficient by this becomes $\frac{X \times V^3}{I.HP.} = 943$ = co-efficient.

The mean horse power indicated was 866, and the truth and balance of the engines were such that they could be run in dock as slowly as eight revolutions per minute without stopping. The vessel was built by W. Gray and Co., of West Hartlepool, and is owned by Pynam Brothers, of London

* * * * *

In the foregoing description of the Enfield it is to be regretted that no particulars are to hand of the boilers, or of the quantity of coal consumed in developing the given power, for the amount of fuel expended in producing the power forms the true test of the economy of a vessel's machinery.

Generally speaking then, the most important point towards economy and efficiency of working is to have the boilers made of ample size, also the condenser, and the air and circulating pumps. The formulæ given in books for the proportions of these parts are sometimes misleading, and in designing a steamer and estimating her probable speed, these proportions should be considered with relation to the climate in which the vessel will be engaged, the temperature of the injection water with which the condenser will be supplied, and the quality of the fuel to be obtained, a fair allowance being made for fouling of the vessel's bottom, accumulation of scale on the boiler plates, and fouling of the condenser tubes.

A better result is also obtained where simplicity of design is observed in the engines, and where the stroke of piston and length of connecting rods bear a good proportion to the diameters of the cylinders. A good result is seldom obtained from short dumpy engines.

It is also desirable to leave plenty of room in the boilers, between the furnace, combustion chambers, and tubes, so that they may be quickly and easily cleaned and repaired.

Everything which tends to economy and reduction of labour in a vessel is not only a saving in itself but is a direct source of gain, inasmuch as the very best class of men may easily be obtained to work the vessel. Every steamer also should be well supplied with gear and the necessary tools to effect repairs in the event of accident.

The causes which act most quickly in decreasing a steamer's speed are fouling at the bottom, and deposit of scale on the heating surfaces of the boilers. Although much thought has been given to these important subjects, no preventives appear yet to have been brought forward which possess sufficient merit to ensure their general adoption.

* * * * *

In conclusion, it may be observed that, no matter how much pains are taken to ensure a well constructed and reliable set of engines and boilers, and a well found vessel in all respects, very much depends upon the management of them by those placed in charge.

A want of cleanliness and discipline in a ship usually lead to more expense than years of fair wear and tear.

The writer is acquainted with one vessel in which the bilges were kept in such a disgusting state that a gallon of disinfecting fluid was obtained by the chief engineer with the stores every month and poured in the bilges to keep down the stench from them. It is needless to add that the management of the engine-room in this vessel, and the state of the machinery generally, were in a correspondingly disgraceful condition.

Next to the boilers the bilges and pump strums perhaps deserve attention, for when these are neglected the bilge pumps soon become choked by the dirt washed up by the rolling of the ship in bad weather. Dirty bilges also cover the bright work of the engines with rust, and destroy the paint, thereby causing trouble and expense.

* * * * *

In closing this paper attention is drawn to the fact that the quality and efficiency of a crew depend mainly upon the character and competency of those above them. Few men suffer more personal discomfort than those who follow the sea ; and no class of men, especially in a climate like that of our northern coast, earn their living harder than do firemen. The writer takes this opportunity of doing justice to our colonial firemen by stating that even under these adverse conditions a crew of them may be obtained in a vessel, which for intelligence, sobriety, and faithful performance of downright hard work, will compare favourably with any other class of men in any similar station of life.

It will be found good policy to give attention to those details, which may lighten the labours and promote the comfort of the crew, such for instance as the supply of a bath for the use of firemen coming off watch. These matters, which are often overlooked, have a direct influence on the economy of a steamer. By obtaining a superior class of men in the ship a higher degree of discipline may be maintained, more work is done, the vessel is kept in the best order, and repair lists are reduced to a minimum, so that credit is done to the owner.

MINUTES OF PROCEEDINGS,

16th SEPTEMBER, 1886.

Walter Shellshear, President, in the chair.

The following candidates were balloted for and duly elected:—

Members:

A. T. DUNCAN.
W. REEKS.
W. F. ROBERTSON.
C. S. WILKINSON.

Associate:

J. F. CARSON.

Student:

C. F. KOPSCH.

On the motion of Mr. Smail, seconded by Mr. Pollock, Messrs. J. B. Henson and J. Elder were appointed to make the annual audit of the Society's accounts.

Alteration of Section V., Clause I. of Rules and By-laws.

Mr. Cruickshank moved, and Mr. Mountain seconded,—That the resolution carried at the last general meeting, to increase the annual subscription of members to two guineas, be finally now adopted. Carried unanimously.

A communication *re* forming an "Australasian Association for the Advancement of Science," was received, and on the motion of Mr. Smail, seconded by Mr. Trevor Jones, the President and Vice-President were appointed delegates to attend the preliminary meetings.

Mr. Mountain then read the following paper, the discussion on which was held at a special general meeting on the 23rd September:

NOTES ON PORTLAND CEMENT.

By A. C. MOUNTAIN, M. Inst. C.E.

In undertaking to read before this Association a short paper on the subject of "Portland Cement," the author fears he can contribute but little in the shape of absolutely new matter to the numerous and very scientific researches, the results of which have been presented

to the engineering world during the last few years; nor does he now propose to enter minutely into the question of its chemical constituents and method of manufacture, its early history, and subsequent development. He will confine his remarks rather to the experience he has had—as a large user of cement in important public works—with both English and Continental brands; and will place in tabular form the results of some of the tests that he has carried out in connection therewith, in the belief that they will be of interest and possible information to engineers in the colony, where such detailed examinations of the various properties of cement are but seldom undertaken.

Until within a very few years back, it was the almost invariable practice in Sydney to simply stipulate in contracts that the cement should be "of approved brand," or else one especial brand was indicated; and then—provided the cement seemed to be (in appearance, and to the hand of the practical man) "in good order and condition"—it was accepted and used forthwith. Later on, a certain minimum tensile strain was demanded, being generally 400lbs. to the square inch; and it is to be feared that at the present time but little provision beyond the tensile strength of the material is made by the majority of engineers and architects in New South Wales, notwithstanding the extended knowledge of the properties of good cement that has resulted from the experiments of the English, German, and French engineers and chemists.

When it devolved upon the author to carry out the system of woodpaving now introduced so extensively in this city, he perceived the necessity of making stringent conditions for the quality of the cement supplied; and, in order to do so, he foresaw the necessity of making the supply of cement a special contract, irrespective of the construction contracts. This being decided on, it remained to provide for the tests to which cement delivered under this contract would be required to conform; and in this matter—a delicate action, from its novelty in Sydney and from the apparent severity of its requirements—he was fortunate enough to have the hearty co-operation and valuable assistance of Mr. J. B. Mackenzie, M. Inst., C.E., then resident engineer of the Cockatoo New Dock, who was at the time engaged in framing specifications for the cement to be supplied for that work, and whose experience in that direction is probably equal

to that of any engineer in the colonies. The result is the compilation of a set of tests *(vide Appendix A)* providing for specific gravity, fineness, progressive strength, fitness for immediate use, and purity of manufacture, which—if complied with – will insure an article that is strong, durable and not liable to "blow" or crack in the work.

Many authorities have contended for the weight per imperial bushel to be not less than 110lbs., 112lbs. being deemed a fair average; but now that so much more attention has been devoted to fine grinding of cement, it is evident that the weight is not a reliable test, as the more finely the same material is ground the lighter will it be, bulk for bulk, owing to the larger proportion of interstitial space to the whole volume, hence the introduction of the specific gravity test, which determines with exactitude the volume occupied by a given weight of cement. Careful chemical experiments made by the Doctors Fresenius (of Wiesbaden) show that a genuine Portland cement almost invariably gives a higher specific gravity than will cement which is adulterated either with hydraulic lime, pulverized slag, trass or the other ingredients usually employed as adulterants; and (as the difference in gravity is very slight between the pure and the "hocussed" materials, varying generally only in the *second* decimal) it is necessary to use great care in ascertaining the result of tests for this purpose, and to insist on all cement standing a minimum gravity test of 3.1.

The chemists above referred to give 3.155 as the lowest figure for a genuine Portland cement; and they further give no less than five additional means of detection, viz:—

Loss by ignition.

Behaviour to water; i.e., the alkalinity of the aqueous solution.

Behaviour to diluted acid.

Behaviour to chameleon solution.

Behaviour to gaseous carbonic acid.

When it is remembered that these methods require the knowledge of the chemist and the apparatus of an analyst's laboratory, it will be seen how hopeless it would be to expect any engineer, in practice, to submit each cargo of cement that he receives to the requisite chemical processes thereby implied, before he could ascertain

if he had to deal with a genuine article or not. And yet, for want of that information, failure, which would mean ruin to his professional reputation, might ensue.

The presence of substances which closely resemble the constituents of the cement itself, is admittedly common, especially amongst the German cements; the result is a feeling of uneasiness and distrust in the use of the material, somewhat similar to the doubt that has been but too general among housekeepers regarding the genuineness of the family butter, since the introduction of oleomargarine and butterine; with this distinction, that in the latter case, in all probability no evil result is likely to accrue from the use of the imitation article; whilst in the case of cement, one has to deal with an unknown factor, and the real quality of the material is only discovered by the mischief it occasions, and the possible injury it may do to the reputation of the user.

These facts point to the necessity for establishing an official testing house for cement, which—by preference—should be in connection with the University authorities, where the general character of all cements imported should be ascertained, and a great deal of loss and inconvenience saved both to importers and consumers.

This system is in vogue in Germany, and answers well there; and from its straightforwardness should commend itself to the favourable consideration of engineers in Australia, where we are even in greater need of some such safeguard than are the continental engineers, who are able to know exactly from what factory their cement comes; whereas here we have largely to depend on the assurance of the *casks and labels* as each shipment comes out; hence the folly of specifying for a *brand* of cement, which can be attached to materials of widely different quality, as the author has had personal evidence of. Apart from the chemical testing for the quality of the material, the author's impression is that the other operations of testing (as described in Appendix A) should be carried out by the engineer in all cases where anything like a large quantity of cement is required; and that samples from each ship-load should be taken, and tested (at all events up to the seven-days test) before being passed.

The author has dealt at some length on the question of adulteration from the fact that he has had occasion to meet here in Sydney with cement thus vitiated; and because it is well known that (in Germany especially) not only is the practice very prevalent, but that what is known as "Blast-furnace slag" mixed with lime is sold there under the name of "Pozzuolana Cement," although the investigations recently made by Dr. C. Schumann on its strength, as compared with that of genuine Portland cement, are so conclusively in favour of the latter that it will, he thinks, hardly develop into a profitable industry.

Another most important test is that for expansion, or fitness for immediate use. A cement (included in the tests recorded in the appendix) that showed admirable strength and fineness, frequently failed at this test, which showed that—before it could be with safety used on work—it would require to be opened out to the air, and turned over so as to thoroughly cool, and thus avoid the chance of expansion when used in the shape of concrete, ordinarily termed "blowing" or cracking. By testing in pats (as prescribed in the specification—*vide Appendix A)* and observing during at least seven days their behaviour both in air and in water, the question of the fitness of cement for instant use out of cask is ascertained. No change occurs if the cement is in proper state, but cracks or puffs at the edges are apparent if the cement is "over-heated," or has free lime present. A great deal of the cracking observable in cement work in this city is due to the fact that this point is not carefully attended to. The author has on record the observation made by a brother engineer on two cements which were spread out, side by side, for air-slacking, in order that their fitness for immediate use might be determined. Whilst thus exposed to the action of the atmosphere, one of the cements absorbed moisture to such a degree that a hard crust formed on the surface, just as might happen to a heap of lime exposed to the air after slaking, thus demonstrating the fact of its unfitness for use in that condition. The other cement, under precisely similar conditions, showed no variation of volume, or expansion, showing that free lime did not exist. There is good reason to believe that cement is often packed when in an over-heated state, and that the process of air-slaking in a partial way goes on whilst in the casks; the result being the skin of caked cement next the inside

of staves that is sometimes found in casks free from all indications of damp or sea water. Although cement in this condition is not fit to use at once, and although such cement should be carefully watched, it is not, of necessity, a proof of its being—apart from this defect—a bad article, provided an apportunity exists (and is embraced) to spread and turn over, and allow it to cool for a few days. Along with the above described examination, the observations to ascertain the color and the time taken in setting are also carried on. Nearly all authorities attach a great value to the color of the cement, the best slow-setting cement being of a cold bluish grey tint, the quick-setting being usually of a darker tint; but now that cements are made from so many varying descriptions of limes and clays, experience shows that this dictum should not be *too rigidly* insisted on, as some good cements do not answer its requirements. But, as a general rule, the more nearly the cement approaches the greyish tint, the better are the chances that it is a good sample; whilst all earthy looking, yellowish, or dull brown cements should be looked on with suspicion. A good cement, when mixed up in mortar or concrete, frequently shows a decidedly greenish tint.

To ascertain the time taken in setting, the cement is made into circular pats tapering to a wafer thickness at edges, which are subjected to the pressure of a wire one-sixteenth of an inch in diameter, and weighted to the extent of 1lb. avoidupois (325lbs. per square inch, or 20·87 tons per square foot.) This is applied from time to time, until the wire makes no indentation on the cement, when the latter is deemed to be set. If this result is arrived at within two hours, it is "quick-setting;" if a longer period is taken, it is called "slow-setting." The latter is the stronger in the long run; the quicker-setting cement generally starting off with a higher initial strength, but arriving at its ultimate strength sooner. There are, however, many works (such as water-works, and where time is a great consideration) for which quick-setting cement is well adapted.

In mixing cement for briquettes to ascertain the *tensile strength* of the material at various periods, great care and uniformity is required on the part of the manipulator, so as to produce the same class of briquette on all occasions. A very slight excess of water will make a great difference in the result. For "neat" tests the

proportion of water needed varies (according to the cement) from 15 to 25 per cent.; for "three to one" tests from 9 to 10 per cent. is usually sufficient. As little water as possible should be used. The sand and cement are mixed together mechanically by a revolving beater working in an enclosed basin, the same number of revolutions being given in all cases. Once mixed, the materials are at once transferred to the gun-metal moulds, which rest on iron plates; it is well pressed and crammed into moulds until flush on face, when the briquettes are sufficiently firm to permit of the moulds being removed. They are then kept for 24 hours in a moist atmosphere, and then placed in trays containing water, until the arrival of the different testing periods.

Although a high tensile strain is expected in the tests, it is undesirable to see that result obtained too rapidly, as it is by the steady progressive increase of strength with time that the best cements are known.

This is illustrated by reference to table B (in appendix) where the cement numbered G starting at the 3 days neat test at 354lbs., acquires at 12 months the very respectable strength of 922lbs., and shows during that period constant progression; also, the same material at the 3 to 1 test commences at 7 days with the modest strength of 93lbs. (or only just above the minimum requirement) and, at 12 months, breaks at 424lbs., and shows no indication of having attained its ultimate strength. It will be noticed that many of the other examples which start with a greater initial strain, at the end of the period of 12 months have not acquired an equal power of resistance to tensile strain.

N.B.—The appendices above referred to, and which are attached to this paper, are:—

A.—Extract from specification for supply of cement to the city of Sydney, giving clauses relative to the testing; also a copy of the test-form.

B.—A summary of tests of various brands of English cement, complete up to date, tested by the author for the Municipality of Sydney.

C.—Similar to B, but of German and other continental cements.

Amongst the minor matters to which the author's attention was directed in connection with the floating or rendering for the concrete wood-paving was the question as to the extent to which water could be used in mixing the mortar without impairing its strength. Whilst it is obviously the interest of the workman to use enough water to make the mixture easy to work, it is apparent that the less the percentage of water used, the stronger will be the mortar: at the same time enough water must be employed to let the rendering run easily. To strike "the happy mean" was his endeavour, and to do so he experimented on the mortar as it was then being mixed on the work, and compared it with other tests, with the result that he found that on an average the men were in the habit of using nearly 18 per cent. of water, but that $13\frac{1}{4}$ per cent. of water was sufficient to use for floating in practice, with the advantage that the mortar was $47\frac{1}{2}$ per cent. stronger at the end of 28 days. The result is that he specifies now that *not more than 14 per cent.* of water shall be used for this purpose.

The strengths were as follows:—

No.	Tensile Strength in lbs.		Increase over No. I Test.		Remarks.
	7 days.	28 days.	7 days.	28 days.	
1	100	229			Taken ready mixed from work; containing 17·9 per cent. of water.
2	250	355	150 per cent.	55 per cent.	Materials taken dry from work; guaged with 10 per cent. of water: too dry for floating.
3	237	338	137 per cent.	$47\frac{1}{2}$ per cent.	Same materials as No. 2, but guaged with 13·28 per cent. of water. Found to be sufficient for floating.

In this table it will be seen that the greatest strength of this mortar, which, it may be stated, is of two parts of sand to one of cement, was obtained with only ten per cent. of water. This, however, was practically found to be too stiff to be insisted on.

The author also caused tests to be made to ascertain the relative strength of different materials when made into briquettes with

cement. These were all carried out under similar conditions with the same cement. The materials were thoroughly dry before using and were mixed (by hand) on the slate table of the testing-room ; ten per cent. of water was found to be sufficient in each case.

The proportions are all by weight (3 of aggregate to 1 of cement), but as the weights of the different materials tested vary considerably when equal bulks of each are taken, a comparison was also made in that respect which is attached to the table for general information.

No.	Tensile Strain in lbs.		Increase.	Remarks.
	7 days.	28 days.		
1	145	182	25.5 per cent.	Made with crushed sand-stone, same as for standard tests.
2	127	170	33.8 per cent.	Similar to No. 1, save that the sand was washed and dried.
3	141	183	29.7 per cent.	Nepean River sand as used for floating.
4	114	166	45.6 per cent.	Nepean River sand, thoroughly washed and dried.
5	211	279	32.2 per cent.	Bluestone dust, as used for grouting ; passing through $\frac{1}{8}$ inch sieve.
6	217	306	41.0 per cent.	Equal quantities by bulk of bluestone dust and five-sixteenths screenings.

It will be seen from this table that, both in the case of the crushed sand-stone and the Nepean River sand, an absolute loss in strength was occasioned by *washing* them ; thus indicating that some cementitious property is removed by that operation.

Taking No. 1 the standard for making and testing briquettes as a basis, we find that

No. 2 is 12·4 per cent. weaker at 7 days, and 6.5 per cent. weaker at 28 days.
3 ,, 2.7 ,, do. ,, ,, .54 ,, stronger ,,
4 ,, 21.3 ,, do. ,, ,, 8.7 ,, weaker ,,
5 ,, 45.5 ,, stronger ,, ,, 53.2 ,, stronger ,,
6 ,, 49.67 ,, do. ,, ,, 681 ,, do. ,

In the last two cases (Nos. 5 and 6) the large excess of strength is due to the difference of weight of the materials, thus reducing the bulk in the case of the heavier ones, as is shown in the following table, which gives the actual weights of the different materials, and also the corresponding proportions of volume to weight, and conversely.

No.	Description of Materials.	Weight in lbs. per cubic ft.	Percentage of increase on weight of No. 1.	Ratio of volume to 3 to 1 by weight.	Ratio of Weight of 3 to 1 by volume.
1	*Crushed sand-stone*, as used in ordinary tests for briquettes	83.15	Nil.	2.95 to 1	3.04 to 1
2	*Crushed sand-stone* (but washed and dried.)	92.14	11.1 %	2.67 ,,	3.37 ,,
3	*Nepean River sand* (as used for floating or rendering)	104.77	11.6 ,,	2.35 ,,	3.81 ,,
4	*Nepean River sand* (washed and dried)	106.22	17.6 ,,	2.31 ,,	3.88 ,,
5	*Bluestone dust* passing through $\frac{1}{8}$in. mesh	113.15	22.1 ,,	2.17 ,,	4.24 ,,
6	*Equal bulks* of Nos. 5 and 7	119.71	34.3 ,,	2.05 ,,	4.38 ,,
7	*5-16ths screenings*, passing through $\frac{1}{2}$ inch but not through $\frac{1}{4}$ inch mesh	94.45	...	2.6 ,,	3.45 ,,
8	*1 inch screenings*, passing through 1 inch but not through $\frac{1}{2}$ inch mesh	89.78	...	2.74 ,,	3.28 ,,
9	$\frac{1}{4}$ *inch screenings*, passing through $\frac{1}{4}$ inch but not through $\frac{1}{8}$ inch	91.73	...	2.68 ,,	3.35 ,,
10	River gravel, screened from sand, $\frac{1}{4}$in. to $2\frac{1}{2}$in. gauge	114.90	...	2.14 ,,	4.2 ,,
11	River gravel and sand, as used for concrete	130.67	...	1.96 ,,	4.6 ,,
12	Portland cement, used in test [q²]	81.99	...	...	...

This table shows that whilst the standard material used for cement tests is very nearly equal in weight to the cement employed, (and consequently nearly similar in volume) the greater density of the bluestone screenings causes (in the case of No. 6 in the table) the ratio of volume to be only a little over 2 to 1 for the *weight* test of 3 to 1. Following up this enquiry, the author caused tests to be made, from which the following table is prepared, showing the difference in tensile strength between briquettes in which the materials were proportioned by weight, and those in which the proportions were determined by volume. The numbers correspond with

those previously used; 10 per cent. of water by weight was used in each case, but the briquettes were $1\frac{1}{2}''$ by $1\frac{1}{2}''$ (or $2\frac{1}{4}$ square inches in section,) prepared with the same cement as that previously used (q^2 in table C) and reduced to the square inch strain.

It will be noticed that, notwithstanding these facts, the strains obtained from No. 1, both at 7 and at 28 days, differs from those already recorded at those periods when made with the 1″ by 1″ moulds (*vide* q^2 tests in table C). This appears to point to the fact that the smaller briquettes can be made more dense and uniform in texture than those of larger size, and consequently afford better results in testing.

3 to 1 Tests: Comparative Strength by Weight and by Volume.

No.	By weight at		Per-centage of increase from 7 to 28 days.	By volume at		Per centage of increase from 7 to 28 days.	Extent to which strength is decreased when proportions are by volume instead of by weight, at	
	7 days.	28 days.		7 days.	28 days.		7 days.	28 days.
	lbs.	lbs.	per cent.	lbs	lbs.	per cent.	per cent.	per cent.
1	145	182	25.5	131	159	59.0	10.35	12.17
2	127	170	25.2	107	131	87.1	15.20	22.94
3	143	244	41.3	105	172	63.8	26.50	29.50
4	113	214	89.3	82	155	89	27.60	27.50
5	178	245	37.6	119	177	48.7	33.10	27.70
6	221	330	33.0	143	218	34.4	35.20	33.90

An attempt was also made to obtain the relative strengths of concrete made entirely of bluestone aggregates, and that made with river gravel and sand, but with hardly satisfactory results, in consequence of the size of the blocks being too large.

The blocks were made in each instance 6 inches in thickness, 9″ by 9″ on the surface, and were gauged 6 to 1 (by volume) of aggregate and cement, with 6.4 per cent. of water for the bluestone concrete, and 5.06 per cent of water for the gravel and river sand mixture.

The "bluestone" aggregate was composed of equal parts of 1″ and 2″ metal, mixed with 50 per cent. of screening passing through a $\frac{1}{4}''$, but not through an $\frac{1}{8}''$ mesh, and of bluestone dust in the proportion of 1 to 2. The weight of this mixture was 121.5lbs. per cubic foot.

The "gravel and sand" aggregate consisted of gravel ranging from $\frac{1}{2}$ inch to 2 inches in gauge, mixed with Nepean River sand in the proportion of $2\frac{1}{2}$ to 1, and weighed 129lbs. per cubic foot.

The same cement was used for both concretes, and three blocks of each kind were made, and sent to Professor Warren's testing room at the Sydney University, to be tested for compression when the concrete was 21 days old, half of which time was under water. Professor Warren, who kindly undertook the test, reported that they presented too large an area for the machine, which is limited to a pressure of 100,000lbs.

One bluestone block cracked *on one side* at 67,000lbs., but there was no sign of crushing at 100,000lbs.; the second did not crack even at 100,000lbs.; and the third was not attempted.

One Nepean gravel block cracked at 54,000lbs., and crushed at 85,000lbs.; the second cracked at 96,000lbs.; but the third did not even crack at 100,000lbs.

The results appear to be in favour of the bluestone concrete, but are not satisfactory; and further experiments with smaller blocks will be made shortly to settle the point accurately.

Several attempts have been made to manufacture Portland cement in the colonies, and a good deal of money has been spent in experiments without much success; the apparent difficulty being to obtain the class of lime that will produce the necessary chemical change—effected during calcination when the lime is mixed with silica and alumina—whereby the carbonates are transferred into silicates of lime.

The author has himself been present at several of these trials, which have resulted in failure, either from the fact of the materials which were employed not possessing the proper chemical constituents, or from defective manufacture. Under these circumstances it may be supposed that he feels pleasure in stating that he has just had his attention drawn to a sample of cement made in Tasmania from materials obtained within some twelve miles of Hobart, which has been exhibited at the recent exhibition held under the auspices of this Association, and which he is now testing. Although, up to the present, the tests have only reached the seven day period, and the ultimate behaviour of the material has still to be cautiously observed, it will doubtless be of interest to inform the members present that —so far—the prospects of this being a genuine and valuable cement

appear to be very good. The tensile strength of the neat cement at 3 and 7 days was 421 and 693lbs. per square inch respectively; and the test of the 3 to 1 briquette at 7 days gave a result of 213lbs. per square inch, which may be regarded as indicative of considerable initial strength. The pats gave no sign of "blowing" or cracks, and the color, which is light grey, is a good tint.

The small parcel submitted to the author hardly justifies the formation of an opinion of the general fineness and weight of the cement; that which was sieved gave a residue of only 1.58 per cent. on the A sieve (of 2,500 meshes to the square inch) which shows it to have been well ground; in all probability it was put through a Chilian mill.

The chemical analysis, by W. A. Dixon, F.I.C. (which has been submitted to the author for his inspection) is of a rather favorable character, being as follows:—

Lime	66.6
Magnesia	1.2
Alumina	4.7
Silica, free	1.9
Silica, combined	19.2
Carbon, combined air and traces of carbonic acid ...	3.1
Oxide of Iron	3.1
Traces sulphuric acid and alkalies	0.2

Mr. Dixon also remarks that "the quantity of lime in this "cement is somewhat in excess of that usually found, whilst the "silica and alumina are deficient. The manufacture has, however, "been so carried out that nearly all the silica is in the combined or "active cementing condition; indeed, of all cements which have "come under my notice, this is the highest, by about one-third, in "combined silica. Under these circumstances the cement should be "very hard setting, should stand sand well if finely ground."

A comparison of the above analysis with that given by Henry Reid, in his work on the manufacture and use of Portland cement (page 354) as the composition of a good cement, viz:—

Lime	60.05	per cent.
Magnesia	1.17	,,
Alumina	10.84	,,
Silica	24.31	,,
Alkalies	1.54	,,

will show a tolerably close resemblance between the two, the chief difference being that the Tasmanian sample is evidently "over-limed," which the maker affirms has been intentionally done, possibly with the idea of increasing the immediate strength.

One peculiarity in this cement is that it took 18 hours to set, a much longer time than any ordinary cement requires.

However, there appears to be sufficient merit in this attempt at the manufacture of a colonial cement to warrant us in wishing the speculators in the venture every success in their praiseworthy undertaking.

In conclusion, the author would apologise for the incomplete character of these notes, as the time at his disposal has been restricted, and the experiments in connection with cement are still being carried on; final results cannot therefore be expected at the present time. He trusts, however, that enough has been shown to prove the necessity that exists in Sydney for a careful and intelligent examination of every shipment of cement that is offered for use on important work, regardless of the utterly misleading recommendation of "brands," or the self-satisfied assurance of the "practical" man who will tell you that he can at once pronounce, by the touch, if a cement be good or bad (a mysterious gift which—if reliable—would be of infinite value, and one before which the most scientific chemists would bow the head!)

There is no doubt that, in conjunction with some excellent cement, a lot of inferior and adulterated material is often shipped to Australia, and offered to the public at a cheap rate. Perhaps this has been already rejected at home, and the manufacturer thinks it will do for the colonial market; perhaps it has been under-burnt; or in all probability it has simply been adulterated with a cheaper ingredient, such as free lime, pulverized slag, or shale; or, if a high initial strength is required, about 2 per cent. of plaster of Paris may have been added.

Danger in such cases is to be apprehended; added to which there is the additional risk of injury through bad packing or wet during the voyage, all of which possibilities conspire to make the selection of cement a very anxious matter, unless it receives the consideration of one who has an intelligent understanding of how to set about the work of judging and determining its merits. That all engineers should endeavour to obtain this knowledge is self-evident;

in support of which it is only necessary to quote the following remarks made by Mr. (now Sir) John Fowler in his presidential address before the Institution of Civil Engineers in the year 1866, when enumerating some of the requirements of a civil engineer :—

"Cement is used, chiefly with sand, in various proportions, accord-
" ing to the nature of the work to be executed; and it is not only
" necessary to possess the requisite knowledge and experience for
" determining the proper proportions of cement and sand for each
" individual case, but it is desirable to have the means of determining
" by direct and repeated experiment the strength and quality of the
" cement which it is intended to use."

How much more that applies at the present day when the use of cement has so wonderfully expanded (especially in its application to concrete work), it is unnecessary to say!

Appendix A.

SPECIFICATION

For the Supply of Cement for the use of the Municipal Council of the City of Sydney during the year 1886.

(Clauses relating to Tests.)

* * * * * * *

" The cement will have to satisfy the following tests, which will
" be conducted in this office, under the supervision of the City Sur-
" veyor or his authorised officer.

" The results of tests made on cement supplied under this
" contract will be made known to the contractor, if desired by him.

" Specific Gravity and tests for adulteration.—The specific
" gravity of all cement supplied under this contract must not be less
" than three and one-tenth (3.10) when carefully tested by approved
" gravimeter; in addition to which—if the City Surveyor deem it
" necessary—further tests by chemical treatment may be made, to
" ascertain if the cement is adulterated by the introduction of any
" foreign matter. Cement of less specific gravity than the minimum
" standard of three and one-tenth (3.10), or which shows any indica-
" tion of having been adulterated, will not be accepted under this
" contract.

"Weight.—The weight of cement will be determined by filling "the standard measure with the cement, allowing it to run in as "gently as possible through a specially prepared hopper, to be struck "off at surface when full. On no account will it be permitted to "press the cement down, or even to allow it to acquire any velocity "in its fall to increase its density.

"The cement to be tested will be weighed as received, unsifted, "and must weigh at least one hundred and five (105) lbs. per "Imperial bushel. It will also be required when sifted, without "rubbing, through a sieve of five thousand eight hundred (5800) "meshes per square inch, to leave a residue not exceeding twenty "(20%) per cent. The sieves used in testing to be those now in use "in the testing-room of this office, and known as Adie's standard "brass wire sieve, or sieves similar in description to them.

"Proportions of cement, water, and sand to be ascertained by "weight and the temperature of the water used, both in the mixing "and in the setting-tank, will be noted.

"The cement to be tested will be made into briquettes, both of "neat cement, and of cement and sand mixed in the proportion of "three (3) parts of sand to one (1) part of cement, with such propor- "tions of water as will be hereafter specified.

"The sand employed in the cement tests to be obtained from "crushed sandstone, sifted through a sieve of (400) four hundred "meshes per square inch; and to be caught on a sieve of (900) "nine hundred meshes per square inch.

"Tensile strength will be acsertained by Adie's testing machine; "strain to be applied at the rate of (200) two hundred lbs. per "minute.

"The neat cement briquettes, after being thoroughly mixed "with from (16) sixteen to (20) twenty per cent. of water, according "to the nature of the cement, will be tested at the expiration of (7) "seven, and of (28) twenty-eight days from date of mixing, and will "be required to stand a strain of not less than (400) four hundred "lbs. and (550) five hundred and fifty lbs. per square inch, respec- "tively.

"The briquettes of one (1) of cement to three (3) of sand, after "being thoroughly mixed with from nine (9) to (10%) per cent. of "water will be tested at (7) seven and (28) twenty-eight days after "being made.

"The minimum standard tensile strain at (7) seven days is "ninety (90) lbs. per square inch; and at (28) twenty-eight days "one hundred and forty-four (144) lbs., provided the neat cement "sets in less than (2) two hours, or is what is known as quick setting: "but should the neat cement take more than two (2) hours to set, or "be what is known as 'slow setting,' the minimum standard is "(200) two hundred lbs. per square inch.

"To determine its setting properties, the cement, after being "mixed neat and made into pats, will be tested with a weight "equal to one (1) lb. avoirdupois, pressing on an area of cement "under test equal to that of a circle of one-sixteenth ($\frac{1}{16}$) of an inch "in diameter. When the pressure produces no depression or inden- "tation on the surface, the cement is considered to be set. Neat "cement pats kept in air to observe for colour, and others placed in "water after setting for seven (7) days, to ascertain fitness for "immediate use, and ensure the absence of free lime, will also be "applied as may be deemed necessary.

"The above tests are practically similar to those approved by "the Harbours and Rivers Department of this colony, and are "based upon the official requirements of the London Metropolitan "Board of Works, and the rules and regulations for the supply and "testing of Portland cement adopted in Germany, Austria, and "Russia, being actually lower than the standards therein laid down.

"Any cement that will not satisfy the above tests will not be "approved."

* * * * * * *

"The contractor is to state in his tender the rate at which he "will deliver the cement, in accordance with the conditions of this "specification, at per cask, containing a net weight of cement, "exclusive of cask and packing, of not less than three hundred and "eighty (380) lbs. avoirdupois."

A. C. MOUNTAIN, M. Inst. C.E.,
City Surveyor.

Sydney, October 9th, 1885.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

TOWN HALL, SYDNEY, N.S.W.

No .....

CITY SURVEYOR'S OFFICE, ... 188
(Date of 28 days' test.)

SAMPLE OF PORTLAND CEMENT supplied by....., Manufactured by....., Brand.....

N.B.—Tested in accordance with requirements of Specificaeion for supply of Cement to the Municipal Council during the year 1886
The average breaking weight of six briquettes is taken for the test.

NEAT CEMENT set in..... ..... hours.
SPECIFIC GRAVITY.....
Temperature of water used in mixing.....deg. F.
,, ,, in setting tank.....deg. F.

NEAT CEMENT put in water after setting, and observed for 24 hours for immediate use..... ....

NEAT CEMENT kept in air to observe for color.....

Ref. No.	Description of Test.	Results	Standard Results.	Remarks.
1	Weight, as received, per Imperial bushel ...	.....lbs.	Min. 105 lbs.	
2	Weight, sifted through A Sieve	..... ,,	Min. 95 ,,	Condition of Cask tested
3	Residue on A Sieve (2,500 meshes per sq. inch)	.... per cent.	Max. 15 per cent.	
4	,, B ,, (5,800 ,, ,,)	..... ,,	Max. 20 ,,	
5	,, C ,, (14,400 ,, ,,)	..... ,,	Max. 40 ,,	Gross Weight ,, ,, lbs.
	NEAT CEMENT, WITH.....PER CENT. OF WATER			
6	Tensile strength after 3 days	.....lbs. per sq. in.	Min. 250 lbs. per sq. in.	
7	,, ,, 7 ,, ...	..... ,,	Min. 400 ,, ,,	Increase of Tensile Strength from 3 to 7 days per. ct.
8	,, ,, 28 ,, ...	..... ,,	Min. 550 ,, ,,	,, ,, ,, 7 to 28 ,, ,,
9	,, ,, 3 months	..... ,,		,, ,, ,, 28 days to 3 months ,,
10	,, ,, 6 ,, ...	,,		,, ,, ,, 3 mo. to 6 ,, ,,
11	,, ,, 9 ,, ...	..... ,,		,, ,, ,, 6 ,, 9 ,, ,,
12	,, ,, 12 ,, ...	..... ,,		,, ,, ,, 9 ,, 12 ,, ,,
	1 OF CEMENT TO 3 OF SAND, WITH....PER CENT. OF WATER.			
13	Tensile strength after 7 days	.....lbs. per sq. in.	Min. 90 lbs. per sq. in.	
14	,, ,, 28 ,, ...	..... ,,	Min. *144 ,, to 200 lbs.	Increase of Tensile strength from 7 to 28 days per cent., *according to time of setting.
15	,, ,, 3 months	..... ,,		Increase of Tensile strength from 28 days to 3 mo. p. cent.
16	,, ,, 6 ,, ...	..... ,,		,, ,, ,, 3 mo. to 6 mo. ,,
17	,, ,, 9 ,, ...	..... ,,		,, ,, ,, 6 ,, 9 ,, ,,
18	,, ,, 12 ,, ...	..... ,,		,, ,, ,, 9 ,, 12 ,, ,,

....CITY SURVEYOR.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

Appendix B—ENGLISH CEMENTS.

Reference Nos.	Neat Cement Briquettes—Tensile Strain at						3 to 1 Briquettes—Tensile Strain at					Weight per bushel.		Residue on Sieves.			Hours in setting.	Tests for	
	3 days.	7 days.	28 days.	3 mos.	6 mos.	12 mos.	7 days.	28 days.	3 mos.	6 mos.	12 mos.	As reed.	Sifted.	A.	B	C		Expansion.	Colour.
A 1	372	475	605	...	...	601	155	129	...	...	...	100.62	87¼	17.13	...	...	9	puffing at edges	dull brown
B 1	496	604	762	746	809	820	107	178	207	263	269	107¼	100½	11.81	20.59	36.62	8	no change	grey tints
„ 2	350	422	526	854	...	...	135	205	269	...	...	109	97½	13. 2	21. 3	35. 4	¾	do.	do.
„ 3	619	656	786	..	...	...	151	218	...	...	...	107½	96¾	13. 6	21. 4	36.40	¼	do.	grey and buff tints
„ 4	513	642	712	...	...	...	124	170	...	...	...	106¾	95¾	16. 3	24. 5	36.90	½	do.	do.
„ 5	413	462	578	...	...	...	79	140	...	...	...	106½	97	13. 6	21. 8	35.80	¼	do.	do.
„ 6	571	629	720	...	...	...	119	186	...	...	...	107¾	98½	14. 2	21. 9	35.20	¼	do.	do.
„ 7	405	546	598	...	...	...	100	183	...	...	...	109	102¾	8. 8	19. 0	33.80	¼	do.	do.
„ 8	546	608	677	...	..	...	106	201	...	...	...	103¾	93	15.37	21.87	32.86	½	do.	do.
„ 9	474	529	678	...	...	...	97	189	...	...	...	111½	110.2	12.71	21.12	33.70	¾	slight cracks	do.
„ 10	506	553	621	...	...	...	73	155	...	...	...	109	98.15	13. 9	21.41	34.35	¾	no change	do.
„ 11	303	379	472	...	...	...	99	171	..	...	...	115	104.92	13. 8	22.43	33. 9	¼	do.	do.
„ 12	372	536	621	...	..	...	82	142	...	...	...	107¼	97¾	11. 5	21.20	33.36	¼	do.	do.
C 1	462	572	628	808	866	850	135	178	275	302	320	110	101½	14.96	25.17	41. 7	4	no change	light grey
„ 2	560	609	828	...	...	...	218	262	...	...	...	109¾	107½	3. 0	9. 9	27. 6	1½	do.	do.
D 1	333	437	551	695	743	689	98	167	230	261	310	104½	90	18.64	28.14	40.91	1	no change	brown
E 1	388	417	540	720	662	764	103	162	270	306	377	102½	97⅛	7.67	16.52	34.54	4¼	fine cracks	brown
„ 2	532	603	686	731	744	735	168	217	321	289	369	103½	98⅜	7.07	15. 3	31. 8	5	slight puffing	buff and grey tints
„ 3	388	477	585	809	838	846	139	200	238	302	332	105	97½	9. 9	19. 4	34. 3	6½	no change	equal buff and grey
F 1	381	509	617	773	841	838	102	156	299	363	403	109¾	102⅜	12.20	17.90	33.00	5¼	no change	equal buff and grey
„ 2	426	512	624	770	...	...	80	155	243	...	...	108	99⅜	8.09	14. 8	28. 4	½	do	do.
G 1	354	459	610	674	805	922	93	163	308	331	424	112	105½	9. 2	19.00	38.10	6	no change	buff and grey tints
H 1	487	522	549	745	756	755	156	218	340	420	469	105	98¾	5. 9	12. 5	28. 9	¼	no change	equal buff and grey
I 1	367	472	556	767	782	798	92	149	299	372	412	102¾	95.27	8. 2	17. 3	32. 4	¼	no change	buff and grey tints
J 1	415	515	594	666	780	823	77	165	266	336	420	104½	99	9. 9	18. 7	33. 7	4¼	cracks	buff and grey tints
„ 2	255	292	350	560	...	...	51	125	285	...	...	103¼	96½	9. 5	18. 4	34.05	¼	no change	buff
K 1	221	325	391	531	...	...	44	96	236	...	...	106¼	96¾	13. 4	21. 4	35. 6	¼	no change	buff
„ 2	273	345	438	752	...	...	88	183	250	...	...	105	97	10. 4	20. 1	34. 8	½	do.	buff and grey tints
„ 3	234	324	402	748	...	...	116	189	252	...	...	102¾	94	12. 8	18. 9	35. 0	½	do.	do.
„ 4	261	364	401	602	...	...	84	189	243	...	...	105¾	96¼	12. 5	19. 1	32. 6	½	do.	do.
L 1	541	673	676	...	...	...	153	225	...	...	...	102¾	92	13. 9	21. 9	32. 3	1	do.	equal grey and buff

A. C. MOUNTAIN, M. Inst. C.E.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

GERMAN AND OTHER EUROPEAN CEMENTS.

Reference Nos.	Neat Cement Briquettes—Tensile Strain						3 to 1 Briquettes—Tensile Strain at					Weight per bushel.		Residue on Sieves.			Hours in setting.	Tests for	
	3 days.	7 days.	28 days.	3 mos.	6 mos.	12 mos.	7 days.	28 days.	3 mos.	6 mos.	12 mos.	As recd.	Sifted.	A.	B.	C.		Expansion.	Colour.
A 1	187	280	356	455	488	551	61	85	160	188	262	91½	91¼	.17	2. 5	18.21	10	cracks	grey
,, 2	204	324	480	610	691	730	105	179	229	337	390	94	93½	.08	1. 6	12. 2	6¼	no change	grey and buff
,, 3	306	414	516	638	651	729	116	172	234	331	345	93⅜	93½	.21	1. 5	16. 6	7¼	slight cracking	grey
B 1	714	811	707	910	714	861	219	302	319	363	426	102¼	93½	2.24	11. 9	35. 6	6	no change	dark grey
,, 2	579	600	629	830	879	887	143	265	326	394	...	102	101¼	1. 5	6. 3	25. 6	½	do.	grey and buff tints
,, 3	645	710	833	815	...	...	163	268	350	...	...	106¼	104.1	1. 9	8. 9	31. 0	½	do.	light grey
,, 4	663	735	771	998	...	...	195	321	315	...	...	106	102½	2. 3	11. 4	33. 4	2	slight cracks	grey and buff tints
C 1	492	521	662	682	789	840	124	195	252	316	400	96⅜	92	4.26	9.74	25.	7½	no change	dark grey
,, 2	488	573	578	753	776	821	144	203	304	319	408	99¼	93½	4. 2	9. 8	22. 5	7	do.	do.
,, 3	418	473	572	722	829	816	116	185	269	317	382	98⅜	93½	5. 8	12.05	27.24	7½	do.	do.
,, 4	429	500	634	745	778	792	139	206	231	296	339	95¼	89½	3. 6	8. 2	22.	6½	do.	do.
,, 5	409	538	694	758	775	876	104	149	356	428	509	99	93.6	1. 4	4. 2	16. 6	1	do.	buff and grey tints
,, 6	488	705	726	839	853	848	196	280	405	470	506	102	98.5	.28	2. 1	14. 9	5½	cracks	do.
,, 7	491	770	853	...		...	148	257	...	...	...	100	97.9	1.18	8.02	22. 5	4¼	do.	light grey
D 1	240	322	402	490	547	607	64	126	244	291	354	96⅜	95¾	1. 9	8.18	22.98	10	cracks and puffing at edges	brown
,, 2	285	388	430	527	640	679	87	134	220	290	405	96½	94⅛	3. 2	10.	24. 8	8½	no change	buff and grey tints
E 1	573	575	712	746	760	882	185	182	267	328	317	103⅛	103	.9	7.81	32. 5	5	no change	brownish grey
F 1	402	435	599	744	770	820	99	157	331	360	427	97¼	92¾	.82	7. 4	23. 2	¾	no change	grey and buff
,, 2	338	520	608	801	824	792	128	188	256	381	451	94¾	90½	. 2	3. 8	21. 8	1	do.	grey
G 1	165	237	335	370	541	621	49	88	185	275	351	98½	97½	.28	1. 9	16. 1	7	cracks	buff and grey
H 1	307	491	606	702	729	686	127	202	271	356	473	101	96¼	2. 1	5. 9	18. 3	7¼	no change	light grey
I 1	427	557	648	764	822	826	125	207	371	426	468	101⅓	95½	.07	2.	19. 9	¾	no change	grey and buff
J 1	363	613	775	804	909	904	114	170	292	351	374	111.25	101.19	13.12	24.26	42. 8	6½	no change	grey and buff
K 1	307	491	606	702	729	765	127	202	271	356	457	101	96¼	2. 1	5. 9	18. 3	7¼	no change	light grey
L 1	305	469	572	694	754	772	104	166	259	354	384	101½	101¼	1.02	4.42	19. 6	7¼	no change	buff and grey
,, 2	377	456	613	...	...	...	100	144	...	...	...	103¾	102½	.42	3. 9	23. 7	6¼	do.	do.
,, 3	401	460	614	...	...	...	142	189	...	...	...	109¼	109¼	.24	2. 4	20. 5	4½	do.	do.
,, 4	318	427	576	...		...	89	151	...	...	...	110	107¾	.28	3. 3	23. 7	6	do.	light grey
M 1	116	270	388	590	675	729	38	96	185	269	321	101	93¾	4.05	12. 1	26. 9	3¼	no change	grey and buff
,, 2	326	457	566	748	827	837	97	172	273	325	387	102	99¼	2. 8	11. 1	28. 4	1¼	do.	light grey
,, 3	370	465	516	636	...	...	77	131	278	...	...	101½	97½	4.25	14. 5	29. 4	1¼	do.	dark grey
N 1	352	398	463	656	710	830	50	106	196	265	...	109⅜	101¼	12. 9	23. 3	37. 7	2	no change	buff and grey
,, 2	258	306	431	582	695	...	57	115	217	276	...	107	97½	12. 1	19. 8	33. 9	1¼	slight cracks	buff
O 1	468	514	609	699		...	185	225	313	...	...	98½	96½	3. 2	8. 5	20. 9	1¼	no change	grey
P 1	525	565	672	813	...	...	187	308	338	...	...	104½	100¼	2. 2	9. 8	31. 5	¾	bad cracks	buff and grey
,, 2	489	592	675	...	...	...	178	226	...	...		105¼	103¾	2. 1	10. 3	31. 5	4	no change	do.
Q 1	419	530	620	799	863	806	142	235	287	335	392	107¼	105½	1. 9	8. 2	27. 2	2	no change	light grey
,, 2	423	532	738	...	...	...	181	268	...	...	...	105¼	102½	2. 5	9. 5	26. 3	4	do.	grey, buff tints
,, 3	406	470	572	...	...	...	172	262	...	...	...	97¼	95¾	2.39	7. 4	23. 3	3½	do.	light grey
R 1	410	472	578	...	...	...	131	199	...	...	...	108¼	106	3. 5	13. 0	37. 3	4	cracks	buff and grey

A. C. MOUNTAIN, M. INST. C.E.

DISCUSSION.

Professor Warren remarked that the author had placed before the members of the association the results of his own experiments on Portland cement, and like most experimenters on this material, he had confined his attention to the tensile strength rather than the compressive or transverse strength. There could be no doubt that a cement which possessed a high tensile resistance would behave well when subjected to compressive or transverse stresses. Indeed, in comparing the results of testing cements, both in tension and compression, it was seen that the ratio of the strengths are approximately the same. Hence engineers preferred the tensile test to that of compression, or cross-breaking, in judging of the quality of the material, and in every specification was to be found a clause governing the supply of cement of a given tensile strength.

In designing works, however, the information obtained so carefully on the tensile strength, would not help the engineer in providing the necessary sectional areas to resist the various stresses which might be developed in the structures in which Portland cement was so extensively used.

Cement, whether mixed with sand to form mortar, or with aggregate to form concrete, was rarely ever in direct tension, but more frequently in compression, or it was called upon to resist stresses which were analagous to those developed in a beam when subjected to transverse stress.

As examples of direct tension we had the resistance offered by a joint in a brick-in-cement wall for retaining earth or water, when the line of pressure passed too near the outer edge, but here the adhesive strength of the joint was so much less than the tensile strength of the mortar, that it would be separated from the bricks long before its full tensile resistance was developed.

In larger structures of this class the material should be so disposed that the line of pressure in no case passes so near the edge of the wall as to develope the tensile and adhesive resistance of the mortar, and this rule was uniformly observed.

In the concrete filling of bridge cylinders the material would generally be subjected to direct compression. Under severe wind pressures, however, the piers, acting as cantilevers, would deflect, and the concrete would then undergo transverse stress.

In the foundations for timber pavement the material was also subjected to transverse stress, and its thickness should be determined rather to resist these stresses than those of direct compression. If we imagined the material, upon which the 6-inch layer of concrete rests, to have subsided partially, then the concrete would undergo stresses analagous to those developed in a beam. The unequal deflection produced by heavy concentrated loads would also develope similar stresses.

He considered that the thickness of concrete foundations for buildings, sewers, retaining walls, and columns should be determined in a similar manner to that of the depth of a beam of a given strength and stiffness, and that the same may be said of concrete landings and floors.

Since, therefore, concrete was so often subjected to transverse stress it was important for the engineer to know the modulus of rupture for the mixtures he intended to use. This could only be determined experimentally. We could not derive the modulus of rupture (excepting approximately) in concrete from the tensile or compressive resistance. It had been proposed by Mr. Deacon, M.I.C.E., of Liverpool, to specify that samples of pure cement should be gauged with water and pressed into a mould $10'' + 1\frac{1}{2}'' + 1\frac{1}{2}''$. The block of cement thus formed should be placed in water, and after seven days tested by placing it on supports $9\frac{1}{2}$ inches apart and gradually applying a load of 150 lbs. on its centre. If more than one block out of three were broken within one minute of the application of the load the engineer or architect should have power to reject the whole of the cement from which the samples were taken. This test could be made by anyone at a cost of a few shillings. The modulus of rupture may be derived as follows :—

Set w = breaking load in lbs.
l = span in inches
b = breadth ,,
d = depth ,,
f = modulus of rupture

$$\frac{w\,l}{4} = \frac{b d^2 f}{6}$$

$$f = \frac{3wl}{2bd^2}$$

The value of f derived from Mr. Deacon's test—

$$f = \frac{3 \times 150 \times 9.5}{2 \times 1.5 \times 1.5 \times 1.5} = 633 \text{ lbs. per square inch}$$

Mr. C. Coleson, A.M.I.C.E., described some experiments in a paper, printed in Proc. Inst. C.E., vol. LIV., page 264, on the transverse strength of concrete beams, the aggregate of which consisted of six parts of harbour shingle, mixed with three of sand and one of Portland cement. This quantity of sand was found to be necessary in order to fill up the interstitial spaces in the shingle.

1. A beam 21 inches wide × 9 inches deep, on supports 8′ 3″ apart, broke with a weight of 5 cwt.

$$f = \frac{3 \times 560 \times 99}{2 \times 21 \times 81} = 49 \text{ nearly}$$

2. A similar beam 3′ 9″ span broke with 1.04 tons, from which f=32 lbs. per square inch.

3. An experiment made by Mr. J. B. Mackenzie on a similar beam but made with purified coke aggregate gave the value of modulus of rupture = 383 lbs. per square inch.

For ordinary concrete the value of f may be taken at 100 lbs. per square inch.

The adhesion of the cement mortar to the various materials which were used in the manufacture of concrete was an important matter, as it determined the strength of the resulting concrete. Experiments on this point had not been as complete as was desirable. The adhesion of mortar to bricks of various qualities when subjected to tensile and shearing forces was also a matter upon which experimental data was wanting. It could hardly be taken as demonstrated that smooth pebbles formed a better aggregate than angular fragments of the same material, although it was considered by some engineers that the adhesion of the cement to the smooth surface of the rounded stones more than compensated for the interlacing of the angular fragments. A series of crushing tests would settle this point.

The following table gave the crushing resistances of bluestone and sandstone concretes. The blocks were prepared by Mr. J. Smail, District Engineer, Sewerage Works, Botany.

UNIVERSITY OF SYDNEY.

Tested by Professor Warren.

Description.	Date when made.	Months old.	Size.	Weight in Pounds.	Total crushing force in pounds.	Crushing force per square inch in pounds.	Remarks.
Sandstone Concrete—							
Cement: Sand : Stone : : 1 : 2 : 5	June 1883	37	6 x 6 x 6	17.5	43,000	1194	Cracked at 30,000 lbs. Two specimens gave each same result
Broken Pipes Concrete—							
Cement : Sand : Stone : : 1 : 2 : 5	,,	37	6 x 6 x 6	16.5	53,900	1497	Cracked at 36,000 lbs. Two specimens gave each same result
Cement Mortar, 1 : 2	,,	37	6 x 6 x 6	15.25	28,700	787	
Bluestone Concrete—							
Cement, Sand, Stone : : 1 : 2 : 4...	Dec. 1884	16	3 x 3 x 3	...	10,000	1111	
,, ,, ,, ,, ...	,,	16	3 x 3 x 3	...	10,500	1166	
,, ,, ,, ,, ...	,,	17	3 x 3 x 3	...	10,750	1194	
Cement: Sand : Screenings : : 1:2:4	,,	17	3 x 3 x 3	...	7,000	777	

A similar experiment had been attempted yesterday with blocks 9″ x 9″ x 6″ in the University testing machine, but they all, excepting one, stood more than 100,000 lbs., which was considerably higher than was expected. These blocks were made by the author (Mr. Mountain.)

He quoted Mr. Grant, M.I.C.E., who gave 933 and 833 lbs. per square inch as the crushing resistance of cement concrete formed with Thames ballast in the proportion of one of cement to six of ballast.

The crushing resistance of some other building materials was for

Good Bricks	about	200 lbs.	per	square	inch.
Portland Cement, neat,	,,	5000 ,,	,,	,,	
Pyrmont Stone	,,	,, 5000 ,,	,,	,,	on bed.
Portland Stone	,,	,, 2693 ,,	,,	,,	,,
Bramley Fall	,,	,, 5000 ,,	,,	,,	,,

Mr. Jones expressed his satisfaction at Mr. Mountain's contribution to our knowledge of the qualities, properties and performances of Portland Cement as imported into Sydney. He was aware of what large quantities Mr. Mountain used on the streets of Sydney, whereby his opportunities were valuable, and also of the excellent means provided by the City Council for testing. He entirely concurred with Prof. Warren's comment, that as Portland Cement was chiefly employed to sustain pressure, the test of its resistance to that force and also to crossbreaking as a beam would bear more directly on its suitability. The figures furnished from the author's and Mr. Mackenzie's experiments would prove valuable aids in the hands of engineers, and his persistence in setting up a high standard of quality among the requirements of his office would go far to suppress attempts to forward to this colony the refuse of the European markets, it would moreover incite manufacturers to keep up the quality in order to retain the custom. The facts relating to the exposing of cement for a time to the action of the air, to counteract the effect of the cement being packed hot, and of the presence of free-lime, which induced expansion after or in the process of setting, was no doubt a valuable precaution if practicable, but owing to the atmosphere in Sydney being frequently very largely charged with moisture, he feared that the cement would sometimes be prejudicially affected thereby. The process moreover entailed a loss of time, and required a space not always available, and generally the soundness obtained in the concrete used on the city streets

without this treatment seemed to render it unnecessary, excepting for works requiring to be thoroughly watertight. In assuming a co-efficient for the strength of cement to resist given stresses, a margin would always have to be allowed, but every set of experiments would tend to narrow the limits of such margin. He felt personally indebted to Mr. Mountain for making public his experience on the question.

Mr. J. M. Small said that having listened with great pleasure to the paper read by Mr. Mountain on such an important subject as Portland cement, he must congratulate him for placing on record information which would be of the greatest utility to those whose professional duties were connected with the construction of works in which Portland cement played an important part. The object in testing cement was to ascertain its fitness for certain work, whether on land or in water, and every engineer had to judge as to the quality of cement which formed the matrix of the material to be used in the work, and it was according to the manner in which such tests were carried out that the work would be stable or not. If such an end could be attained it would be better to have one uniform system of testing, not only with regard to cement, but all materials used in construction. In some cases engineers specified the cement to stand a high tensile strain after seven days, while others preferred a minimum strain at three days and showing a proportionate increase of strength at seven and twenty-eight days respectively. He thought it was obvious that the latter was most calculated to give good results and be an element of strength in the work. He could quite concur with Mr. Mountain in his remarks about earlier specifications specifying "approved brands," also one "particular brand," but it would have to be remembered that at that period there were no machines in the colony for testing cement, and the brands then imported were few, also that concrete so largely used at present, was little thought of. The first system of testing cement before it was used in work was introduced by Mr. W. C. Bennett, M. Inst. C.E., the Chief Engineer for Roads during the construction of the iron bridges over Parramatta River and Iron Cove, in 1879. The machine used was on Bailey's pattern, the weight being applied by water passing, by means of a pipe, from a reservoir on top of standard to a cylindrical vessel at end of lever, a shut-off cock was connected by a rod to the lever, and when fracture of briquette took place the descent of the lever shut the cock and prevented the water passing to the vessel. Attached to the vessel was a gauge-glass ; the water rising in

same shewed the weight in pounds at which the briquette was broken.* The briquettes were $1\frac{1}{2}'' \times 1\frac{1}{2}''$, made in gun-metal moulds. On the commencement of the new system of sewerage works every parcel of cement used on the works had been put through a system of tests to ascertain its suitableness for same. The standard tensile strain had been fixed at 445 lbs. per square inch, after seven days old, and fineness of grinding to be such as to only leave 2 per cent. after being passed through a sieve of 35 meshes to the lineal inch, and when compared with results given in tables of tests given by Grant, Faija, and other authorities, the test could not be considered other than moderate. Even with this moderate standard many of the earlier brands could not come up to it. Mr. Mountain was of opinion that the weight test was not reliable. There was no doubt that taken by itself it was not a sufficient guarantee of the cement being first-class, but when taken with other conditions there was a certain amount of reliability with it as to make it of sufficient importance to be included amongst the tests. In a paper read before the Inst. of C.E., by Mr. Grant, vol. LXII., he said :—"To judge of the quality of cement by its weight alone, without regard to raw materials of which it is made, is impossible, but having regard to these, it is within certain limits one characteristic of strong cement, and it is desirable that it should be ascertained as nearly as possible." With regard to specific gravity, Mr. Grant said in a discussion on a former paper, "Mr. Bramwell suggested that it would be better to ascertain the specific gravity than the weight of cement. The author still ascertains the weight of cements in a manner which has been described, and he has for a long time for experimental purposes, but without practical benefit, taken their specific gravity." In the discussion on this paper, Mr. Faija says "that he was surprised that when Mr. Grant alluded to specific gravity he did not take it in combination with the weight per bushel. The two together afforded a fairly accurate measure of the value of cement. A heavy specific gravity and a heavy weight per bushel would indicate a finely ground cement, whereas a light specific gravity and a heavy weight per bushel was almost sure to be a coarse one." If, therefore, an engineer wished to have a strong, finely ground cement, it would be necessary to have the two requirements, viz., weight and specific gravity. There was another

* This machine is now substituted by one of Adies' latest, fitted with a patent automatic regulator for regulating the application of the weight on lever.

important element in testing of cement, and that was the uniformity and time of applying the weight. In a table given by Mr. Faija, in a paper read before the Inst. of C.E., vol. LXXV., some very interesting results were given of experiments made on this point.

No. of Briquettes.	Speed.	Average result lbs. per square inch.
	lbs. sec.	
129	100 in 1	560.75
129	100 ,, 5	506.43
145	100 in 15	452.20
145	100 ,, 30	430.96
90	100 in 30	417.27
90	100 ,, 60	403.05
40	100 in 60	416.75
40	100 ,, 120	400.87

From the foregoing results it would be seen that the increase per cent. due to increased speed of applying strain was as follows. Taking the lowest speed of 100 lbs. in 120 seconds as a starting point by applying the strain at the rate of

100 lbs. in 60 seconds, the increase was 3.96 per cent.
,, 30 ,, ,, ,, ,, 7.488 ,,
,, 15 ,, ,, ,, ,, 12.416 ,,
,, 1 ,, ,, ,, ,, 23.142 ,,

The size and moulding of briquette was also worthy of consideration. The one inch section appeared to be the one adopted by experts in England and the Continent. To fill large moulds required an amount of mortar, which, if gauged at one time, would be useless for testing purposes, as by the time one or two moulds were filled the mortar would have commenced to set, and if used for forming briquettes it was questionable if useful results would be obtained ; on the other hand, if one or two gaugings were required to fill the moulds, it was quite probable that the results obtained from briquettes would vary very much for the reason that it was almost impossible to mix two gaugings exactly alike. To obviate this, the smaller briquette had been introduced in England, having been the recognised size for some time previous on the Continent of Europe, and a further improvement had been introduced by Mr. Faija in his cement gauger. The machine was 10 inches in diameter and 6 inches high, gauged about 4 lbs. of cement

at a time, which was sufficient for 10 briquettes of the 1 inch section. Some experiments had been made with cement as to its settling capabilities and strength when mixed with salt water. For some time it had been thought that the use of salt water for concrete was injurious, but when viewed by the light of actual experiments it would be seen that under certain conditions the mixing of concrete with salt water was advantageous as regards strength. Mr. Faija had, in a paper read before the Inst. C.E., vol. LXVII. of Proceedings, given some very interesting results of tests with salt as compared with fresh water for mixing. The cement used had been considered only as a fair sample of ordinary commercial manufacture.

Weight per standard bushel	112 lbs.
Specific gravity	2.97
Fineness on No. 25 sieve	nil.
,, 50 ,, ...	18 per cent.
,, 70 ,, ...	25 ,,
Time taken to set when gauged with fresh water	25 minutes
Gauged with sea water	120 minutes

Amount of water used in gauging for sea and fresh water was 17.24 per cent.

No. 1	was gauged	with	sea	water	and placed in	sea water.
2	,,	,,	,,	,,	,,	fresh ,,
3	,,	fresh	,,	,,	,,	sea ,,
4	,,	,,	,,	,,	,,	fresh ,,
5	,,	sea	,,	and left in air.		
6	,,	fresh	,,	,,	,,	

He had selected from numerous results tests made at 7 days and 12 months.

7 Days Tests.

No. 1	470 per square inch.
2	425
3	634
4	512
5	418
6	526

12 Months Tests.

No. 1	835
2	764
3	1064
4	840
5	1120
6	1060

From these experiments it would be seen that the highest result was obtained at twelve months with briquettes gauged with sea water and left in air, next in order came cement gauged with fresh and placed in sea water. From a few tests made by himself with cement mixed with salt and fresh water, the average results were :

	7 days test.
Mixed with fresh water	460.74lbs.
,, salt ,, ...	493.06lbs.

Mr. Faija thought that the deductions to be made from his experiments were "that the salts in sea water have a damaging effect on cement gauged with sea water and afterwards immersed in either see or fresh water ; but a beneficial one when the cement is only exposed to the action of the air, and further, that the same salts have a highly beneficial effect when acting in cement gauged with fresh water, and that for all marine purposes those portions of the work which are above high water, should be gauged with sea water, while those portions which are below the water level should be gauged with fresh water." The introduction of appliances and a system of testing by all the Government departments, and the City Council had greatly improved the quality of cement imported to this colony, and had proved a protection to the manufacturers who would not manufacture anything but a first-class article ; while at the same time deterring some exporters from turning the colonies into an Imperial dust bin to shoot rubbish into.

Mr. Fischer said that while he agreed in the main with the contents of Mr. Mountain's paper, which was without doubt a valuable contribution to the Society's first annual volume, he felt it incumbent on him in common justice towards the German cement manufacturers, —who, Mr. Mountain informed us, had of late attempted to supply the market with adulterated cements,—to bring under the notice of the members the following resolutions passed at the sixth general meeting of the Society of German Cement Manufacturers, held at Berlin in March 1883, and at which no less than 57 manufacturers of cement had been present, including those who enjoyed the best reputation. He thought it would be too tedious although he had no doubt that it might prove interesting to some of the members, to enumerate all the tests that had been made by the highest authorities, such as Dr. Herzog, Dr. Delbruck, Prof. Bernouilly, &c., for the purpose of arriving at some definite conclusion on this question of adulteration. Consequently he should only give a translation of the resolutions passed at

that meeting, which they had proposed should be embodied in an Act of Parliament for the German Empire. This latter suggestion was afterwards supported by the officers of the Imperial Laboratory for the testing of the building materials, who, being perfectly disinterested parties, should be well able to form impartial and reliable opinions on the injurious practice of adulterating cements. The resolutions read as follows :—

I. Portland Cement is a product that is obtained by thoroughly mixing lime and clay together, as principal constituents, the mixture being afterwards burned to clinkers, and ground to the fineness of flour.

II. Any compositions produced in a different manner, and to which are added foreign constituents, either while or after being burned, are not to be regarded as Portland Cement ; an admixture of 2 per cent. or less of gypsum being excepted.

III. The sale of cement, containing an admixture of foreign substances, under the designation of Portland Cement, is therefore to be considered as a fraud on the consumer.

IV. Good Portland Cement cannot be improved by the admixture of foreign substances, such as blast furnace slag, clay, slate or lime-stone. But even if in an isolated case such an improvement might be demonstrated by the use of these admixtures, they should not be permitted, for the reason that the consumer is not able to control the quantity or quality of these admixtures, and is thereby unable to protect himself against being defrauded.

V. The addition of every such admixture is to be considered as a step in the preparation of mortar, the making of which should not be commenced by the manufacturer, but should be left to the discretion of the consumer.

VI. As the standard tests, when determined on, were not intended to apply to Portland cement mixed with foreign substances, and as furthermore the special character of Portland cement becomes changed by such admixtures, therefore these standard tests cannot be used in making comparison between adulterated and pure Portland cement.

Signed by the Council of the Soc. of Germ. Portl. Cem. Manufacturers.

He (Mr. Fischer) thought that the above would conclusively show that this question of adulterating Portland cements had been considered by the persons most interested in maintaining the good character which German cement had enjoyed until lately, and it was to be hoped that if these resolutions had not as yet been passed into law, they would soon become so. To protect the colony against these frauds a short Act of Parliament based on these resolutions might easily settle the question at issue.

Mr. J. B. Henson, after referring to the practical character of the paper read by Mr. Mountain, said that the use of powdered blast furnace slag for adulterating cement, was certainly objectionable, but the employment of the same material as an ingredient in the manufacture of Portland cement had been attended with very good results. The cracks in the test pat of cement exhibited by Mr. Mountain, to illustrate his remarks about the injurious effects of the presence of free (unslaked) lime in cement, were, he thought, ascribed to the wrong cause. The pat appeared to have been set upon paper, whereas the other pat which was not defective had been set upon a smooth hard surface. The cracks in the defective pat were radial, were few in number and appeared in the edges. Cracks due to the expansion of particles of unslaked lime were charaterised by being irregular in direction and numerous, and intersecting each other, destroyed the continuity of the mass. The cracks in the pat exhibited being radial were due to some other cause than the presence of unslaked lime, probably to the material upon which the pat was placed to set, or to shrinkage, possibly to both combined. Very great care and attention were required in the testing of cement. He had seen briquettes broken, showing air bubbles in the line of fracture, and it was necessary before recording a tensile test, to examine the fracture carefully for air bubbles and uniform hardness; for sometimes an unduly large proportion of sand might accidentally appear at the neck of the briquette, when cement and sand mixtures were being prepared for testing. The result of the tests of the strength of concretes made with various aggregates, were particularly interesting. Crushed sandstone, unwashed, produced a stronger concrete than the washed material, similarly with the crushed bluestone. This might be due to the "sap" of the sandstone in the unwashed sample (which sap contained silica in solution) combining with the cement, and increasing the hardness thereof. Washing the crushed sandstone or bluestone, no doubt removed soluble portions which, if left, would enter into

combination with the cement, and increase its hardness and cohesive power. He could not agree with the remarks of the author of the paper respecting the unsuitability of local materials for the manufacture of Portland cement. He (Mr. Henson) had made many experiments, and had obtained very good results. An intimate knowledge of the quality of the raw materials and the process of manufacture were required to insure success. Abundance of materials was available for the manufacture of Portland cement, but the price of good English cement in this market was so low, that the local manufacture could not at present be undertaken with the certainty of producing a profit.

Mr. Burman said that being in the department of which the author of the paper was the head, he had naturally taken a great interest in all work performed in the testing-room. It might be of some interest to many of the members to know that since the beginning of 1885 something like 2964 briquettes 1″ x 1″ section had been broken in the testing machine.

408	...	...	...	At	3	days	neat
408	...	...	...	,,	7	,,	,,
408	...	...	...	,,	7	,,	3 to 1
408	...	...	...	,,	28	,,	neat
408	...	...	...	,,	28	,,	3 to 1
264	...	...	..	,,	3	months	neat
264	...	...	...	,,	3	,,	3 to 1
216	...	...	...	,,	6	,,	neat
216	...	...	...	,,	6	,,	3 to 1
186	...	...	...	,,	12	,,	neat
186	...	...	...	,,	12	,,	3 to 1

The number of briquettes in setting tanks to be broken at 3, 6 and 12 months was as follows :—

At	3	months	= 132
At	6	,,	= 228
At	12	,,	= 228
			648 total

The number of briquettes required for one complete set of tests was

For	3	days	test	neat	= 6
,,	7	,,	,,	neat	= 6
,,	7	,,	,,	3 to 1	= 6
,,	28	,,	,,	neat	= 6
,,	28	,,	,,	3 to 1	= 6

For	3	mos. test	neat	= 6
,,	3	,, ,,	3 to 1	= 6
,,	6	,, ,,	neat	= 6
,,	6	,, ,,	3 to 1	= 6
,,	12	,, ,,	neat	= 6
,,	12	,, ,,	3 to 1	= 6

Total 66 briquettes

The sand required for the 3 to 1 briquettes necessitated the crushing of something like 50 lbs. of stone. The above tests did not include the special tests which would amount to about 18 dozen. When it was considered that each cargo of cement was subjected to tests for fineness, blowing, setting-quality, besides the strain tests, it would be conceded, he thought, that a great amount of time, patience and care had to be bestowed on this work to arrive at accurate results. There was however another step to be taken with reference to testing cement concrete, &c., that was the strain tests of the actual mixtures proposed to be used in different works so as to arrive at the actual gain or loss of strength by admixture with different works, so as to arrive at the actual gain or loss of strength by admixture with different materials of different gauges and quantities, according to the proportions in specifications for different works. He had heard it expressed by some who use cement concrete, that a loss of tensile strength occurred by mixing with salt water. In Grant it was stated that this was not the case, and in vol. LXXX. Proc. Inst. C.E., Kidd on Blyth Harbour, it was stated that a gain was shown in tensile strain, by mixing with salt instead of fresh water. Mr. Henson had mentioned finding blow holes in the centre of some briquettes of small sectional area, he had tested. He was of opinion that this must have been a quick setting cement, as it was often found that minute holes occurred in briquettes of quick setting cement, and was accounted for generally that the cement had begun to set before the ramming into moulds was finished. If, however, any large void space was found in a test briquette, it was at once thrown out. Some cements would set hard enough to bear the pressure of the needle in ten minutes, whilst others would take two hours to become equally as hard.

Mr. Greenwood, noticed that the author had used crushed sandstone as the standard material for mixing with the cement in testing the briquettes. During the time he had been in the colony he had only once seen this material used for mortar, although its use was

very common in England; and it was a common practice in Sydney, when sandstone concrete was being used, to sift the stone and reject the sand, substituting Sydney sand. He would very much like to know the result of tests of briquettes made with Sydney sand (white and yellow), as this material was generally used by Sydney architects, and also in one or two departments of the Government service.

Mr. Shellshear remarked that a small sample of the Tasmanian cement had been tested with the following results :—

Neat cement, set in 9 hours 39 minutes.
,, after 3 days, 453 lbs. per sq. in.
,, ,, 7 ,, 526 lbs. ,,
,, ,, 28 ,, 870 lbs. ,,
Increase of tensile strength between 3 and 7 days, 16.11 per cent.
,, ,, ,, 7 and 28 ,, 65.40 ,,
One of cement to three of sand, after 7 days, 192 lbs. per sq. in.
,, ,, 28 ,, 260 lbs. ,,
Increase of tensile strength between 7 and 28 days, 35.42 per cent.
Neat cement with 18.69 per cent. of water.
One of cement to three of sand, with 11.12 per cent. of water.

This test showed that the cement was of unusually good quality and if cement of equal quality could be made in bulk there would, no doubt, be a great future for the Tasmanian cement. Of late years, cement concrete had come very largely into use for engineering works, and although great progress had been made, there was every prospect of this material coming still more generally into use as its properties became better understood. Perhaps no better material could be used for the linings of tunnels, and it was interesting to note that in the tunnel on the Blayney to Cowra railway this material was now being used. Having had a recent opportunity of seeing this work, he might record that it appeared in every respect better than the old system of brick-lining, as the concrete effectually filled all the irregularities of the excavation, and made a really solid job. There were many cases where concrete in the liquid state could be used with advantage, and in a recent paper read before the association reference had been made to its use for sea-works. It would be very advantageous to the users of cement concrete if a more extensive series of tests were carried out as to the compressive resistance of different mixtures of concrete. The best thanks of the association and the engineering public were due to Mr. Mountain for his very valuable paper, and perhaps the most important part of the paper was that which dwelt on the necessity of

testing samples from each shipment of cement, as unfortunately there was a large amount of spurious material in the Sydney market.

Mr. Mountain, in reply, said he was pleased to find the subject of his Paper elicit such general interest amongst members, and lead to so valuable a discussion, which must be productive of good in directing attention to the importance of this question to engineers generally, and which in all probability was as thorough a debate as had taken place in these rooms until the present time. Professor Warren had given very valuable remarks on the subject of cement, and had, in addition, arranged to test a complete series of concrete blocks of different gaugings and aggregates, also cement mortars of varying strengths, which were now being prepared for that purpose by himself. The results of these tests, which would give accurate comparative results of compressive, tensile, and shearing strains—the tests being all prepared by the one individual—would be of great practical utility, and would doubtless be made known to this association. The remarks of Mr. Henson to the effect that adulteration of cement in some cases may increase its absolute strength, although in opposition to the experience of Drs. Böhme and Dykerhoff, who had investigated the matter, were practically corroborated by the experiments made by Professor Tetmayer, of Zurich, who stated that certain ingredients used for purposes of adulteration (viz., "those containing silicic acid in a state adapted for chemical combination" *(vide Minutes Inst. C.E., vol. 81, page 350)* did not impair the strength of Portland cement, and in some cases actually increased it. But the main point to consider, after all, was the necessity of enforcing the principle that if a manufacturer professed to sell Portland cement, it should be composed of the recognised constituents which formed that material, *and no other*. If he desired to manufacture a preparation containing foreign ingredients, let him do so by all means, but let him not sell it under the name of Portland cement, otherwise the user did not know what he was purchasing, unless by the application of elaborate chemical processes that were unknown to the practical engineer. This was the aim of that meeting of the Society of German Cement Manufacturers, whose resolutions had been quoted by Mr. Fischer, and it was to be hoped that their efforts would be attended with good results. The special reference to German cements as being adulterated occurred in the Paper in consequence of that practice having obtained in that country to a greater degree than elsewhere, but the author quite recognised the excellence of some of the cements of Germau manufac-

ture, which were equal in quality to any cement made elsewhere. With reference to the cracking of the pats, Mr. Henson was in error in supposing that they were not all subjected to precisely similar treatment. The blotting paper was placed between the iron plate and the cement pat in each case, only in this particular instance the paper seemed to have adhered to one of the pats, and had been brushed off the other. The radial nature of the crack was evidently due to the expansion first of all acting on the thin edge—the weakest part—of the pat, and thence extending more or less inwards. Mr. Smail had done well in drawing attention to the fact that salt water was practically as serviceable for making concrete or cement mortar as was fresh water, as this fact—although well known, and admitted amongst engineers generally—had been much disputed by admitted authorities in this city. Mr. John Grant, M. Inst. C.E., had ascertained the usefulness of salt water in this respect many years before the tests referred to by Mr. Smail were conducted, and the subject was not dealt with in the Paper as being one on which the author had not personal experience. Referring to the weight and specific gravity tests, he (Mr. Mountain) considered the latter as of the greater value as it was an invariable record, whereas the weight test varied in direct ratio to the fineness. There was one thing very evident, which was that the weights originally stipulated and obtained twenty years back, were not frequently to be met with at the present time, the result of his experience being that the average weight of cements as supplied to this colony did not exceed for English, 106 to 107 lbs., and for German and other continental, 102 to 103 lbs. per Imperial bushel, and notwithstanding this fact, the standard for tensile strength had been steadily increasing, shewing that the decrease of weight was in many cases due to the fineness of the grinding, which of course enabled the cement to do its work of coating all surfaces of the aggregate more thoroughly in proportion to the extent to which it was ground. The specific gravity test was therefore a substitute for the less reliable one of weight, which was valueless unless considered in relation to fineness. Regarding Mr. Smail's remarks as to the necessity of adopting an uniform speed whilst increasing the weight on the testing lever of machine, he would say that in practice this was recognised, the rate being about 200 lbs. per minute, that being the speed most generally adopted. He had not, however, been able to agree in all particulars with the standards laid down by Mr. Faija, more especially in the small maximum strength that he prescribes for the three days

tensile strain, viz., 275 lbs. A short examination of the tables attached to the paper would show that nearly all the cements (including the best that underwent tests) failed to conform to that limitation, and would consequently have been rejected had the author conformed to its conditions. Also, Mr. Faija's tests for ascertaining the fitness of cement for immediate use (consisting of a vessel containing water heated to a certain temperature, and over which the pats are placed on bars, so as to be subject to the influence of the moist air emanating from the warmed water) had been used by him for a long time in conjunction with the usual method, already referred to, of placing the pats in water for seven days. This had not been attended with successful results, as the latter process had frequently shown cracks in cement that showed no variation of volume when subjected to Faija's treatment. Mr. Greenwood had expressed regret that tests of cements mixed with the ordinary Sydney sand of the building trade had not been made for the purpose of comparing the value of that material with those experimented on by the author. This was certainly an omission which would be speedily rectified, and could be explained only by the statement that this kind of sand had not been largely used for cement work by the author. The reason for adopting crushed sandstone was because uniformity in quality of material used was thereby possible and thus afforded more accurate comparative results than would have been obtainable had sands varying in strength and texture been employed. Crushed sandstone was the material usually adopted for standard testing by engineers, and it was also a valuable sand for mortar. Mr. Greenwood's statement that it was disallowed in certain quarters in Sydney, and preference given to the ordinary sand obtained from the vicinity of the city, was therefore surprising. Respecting the weights given in the paper of various materials used as aggregates, the author would explain that he finds they are in excess of trade-weights of large quantities, having been calculated from the basis of the Imperial bushel, which allowed the particles to be shaken together, and thus packed more closely together than was possible with material loosely shovelled into a box, as is the case in actual work, and where perhaps the measurement was less rigidly conducted: *e.g.*, sand and gravel mixed in the proportion of 2.86 to 1 so as to fill interstitial spaces, gave in the box 121 lbs. per cubic foot, whilst river sand (wet) gave as low as 89¼ lbs. On the other hand, wet river gravel, varying from ¼″ to 4″ in gauge, weighed at the rate of 117½ lbs. per cubic foot, which was in

excess of that given in the paper, which, however, was for *dry* sand. Since the commencement of the discussion, the author had been able to commence some tests illustrative of the respective strength of Sydney sand and the other sands used in the three to one tests. The first instalment of these tests was given now, as likely to prove of interest generally. The tests, as before, were the mean of six briquettes in each instance, and were for the proportion of three to one, both by weight and by volume. The cement used (L in the appendix B) was rather lighter than that previously used for the tests recorded in the paper, which accounted for a slight difference in the ratios of weight to volume. It was intended to continue the observation of these tests for twelve months.

(1) *Crushed Sandstone*, as used in ordinary tests. Weight, 83.15 lbs. per cubic foot. Ratio of volume to 3 to 1 by weight, as 2.8 to 1 ; ratio of weight to 3 to 1 by volume, as 3.11 to 1.

(13) *Sydney Yellow Sand* (from Dowling-street sand-hill) .34 per cent. residue on 900-mesh sieve. Weight, 100.88 lbs. per cubic foot. Ratio of volume to 3 to 1 by weight, as 2.45 to 1 ; ratio of weight to 3 to 1 by volume, as 3.78 to 1.

(14) *Sydney White Sand* (from Dowling-street sand-hill), no residue on 900-mesh sieve. Weight 103.2 lbs. per cubic foot. Ratio of volume to 3 to 1 by weight, as 2.36 to 1 ; ratio of weight to 3 to 1 by volume, as 3.87 to 1.

(15) *Nepean River Sand*, freed from pebbles and fine gravel, $57\frac{1}{2}$ per cent. residue on 900-mesh sieve. Weight, $98\frac{1}{3}$ lbs. per cubic foot, without shaking. Ratio of volume to 3 to 1 by weight, as 2.43 to 1 ; ratio of weight to 3 to 1 by volume, as 3.68 to 1.

(16) *Nepean River Sand*, but sieved through 400-mesh and caught in 900-mesh sieve. Weight, 96 lbs. per cubic foot without shaking. Ratio of volume to 3 to 1 by weight, as 2.48 to 1 ; ratio of weight to 3 to 1 by volume, as 3.61 to 1.

COMPARATIVE STRENGTH OF ABOVE BY WEIGHT AND VOLUME—3 TO 1 TESTS.

No.	By Weight at		Per-centage of increase from 3 to 7 days.	By Volume at		Per-centage of increase from 3 to 7 days.	Extent to which strength is decreased when proportions are by volume instead of by weight, at	
	3 days.	7 days.		3 days.	7 days.		3 days.	7 days.
1	104	191	83.65	102	167	63.72	1.92	12.56
13	43	77	79.06	12	28	133. 3	72.09	63.63
14	132	183	38.64	82	123	50. 0	37.87	32.78
15	123	182	47.96	96	129	34.37	21.13	29.12
16	111	173	55.85	87	127	45.97	21.62	26.59

The above results give some startling evidences of inferiority in the Sydney yellow sand (which in some instances hardly bore the strain of the lever at all) to the ordinary white sand, and shows that none of the sands were equal in strength to the crushed stone, at all events up to the 7-day period. Since the reading of the paper, the result of the 28 days' test of the Tasmanian cement had been obtained, which was 919 lbs. for the neat, and 213 lbs. for the 3 to 1 briquettes. With such results as these it appeared to be now merely a question as to whether the cost of manufacture could compete with the prices at which the imported article was sold. The President, Mr. Burman, and other speakers had pointed out the advisability of prosecuting further experiments, with reference chiefly to concretes of different gaugings. These the author hoped to carry out as opportunity offered, and in conclusion he would express his gratification at the evident appreciation of the subject which had been manifested by so many members, and at the brisk discussion which his paper evoked.

ADDENDUM.

Subsequently to the closing of the discussion on the above paper, the author had his attention directed to the peculiar behaviour of one of the pats of the Tasmanian cement alluded to therein, which gave evidence of deterioration and showed the presence of innumerable and intersecting cracks. Further examination disclosed the fact not only hat this pat was the one which had been placed in Faija's moist air bath, but that both the pat kept in air and the one placed in water

were entirely free from any such cracks or indications of diminished strength or quality. The pat referred to, however, appeared to be steadily perishing, and is now somewhat of the nature of "short-bread," breaking off easily and crumbling at the touch. This unexpected result appears evidently to be a matter which calls for more investigation, particularly as on referring to the different cements (pats of which have been similarly treated) the author has only been able to detect one instance in which a corresponding action has taken place in the moist air bath, that is with the cement classified in the appendix as l^3, and is not nearly so grave in character.

As this development was only detected after the tests had been completed some days, it was impossible to refer to them during the discussion on the paper, but the author thinks the fact of sufficient importance to be noted.

INDEX.

VOL. I.

1885-1886.

A.

	PAGE
Aberdeen Breakwater	105
Accounts of Receipts and Expenditure	6
Act of Incorporation	ix
Addendum to Notes on Cement	256
Address, President's	9
Agriculture, the Mechanics of	149
Air, Compressed, and its Appliances	49
Alderney Breakwater	96
Algiers Breakwater	96
Allen, Percy, elected Member	37
Amsterdam Ship Canal, Breakwater at Entrance	103
Annual Report	1
Arch, the Metallic	166
Australasian Association for the Advancement of Science	220
Awards, List of, Session 1884–5	4

B.

Bagshawe, the Manufacture of Ice	188
Bailey on Economy in Steam Navigation	199
Balance Sheet	5
Ballot for Election of Council, 1885–86	8
Bergin, Francis, elected Member	21
Bergin, on the Metallic Arch	166
Beth Process, on the Manufacture of Ice by the	188
Bread, Manufacture of	27
Breakwaters and Training Jetties, on the Construction of	89
Bridges, Iron *v.* Wood	13
Buckei Breakwater	107
Burman, Remarks on Notes on Portland Cement	249

C.

	PAGE
Carson, J. F., elected Associate	220
Cement, English, Table of Tests	236
Cement, German and other European, Table of Tests	236
Certificate of Test, Cement	236
Charleston Harbour, Training Jetties	112
Colonial-built Harbour Steamers, Our	156
Compressed Air, Past and Present Use	52
Compressed Air, some of the Principles involved in the Use of	56
Compressed Air, some recent Improvements in the Application of	64
Concrete Blocks, Strength of	230
Concrete Blocks, Table of Tests	240
Contents	vii
Copper Ores, Treatment of	21
Corrugated Furnaces, Fox's	201
Cruickshank, Remarks on Paper on Compressed Air	81

D.

Dathis Process, Manufacture of Bread	27
De Burgh, E. M., elected Member	9
Dickenson, Henry E., elected Member	21
Discussion on Paper on Compressed Air	79
Dover Pier	102
Duncan, A. T., elected Member	220

E.

Edgell, Robt. G., elected Student	199
Elder, J., elected Auditor	220
Elevator, Hydro-Pneumatic	49, 69
Engineers under Local Government Boards	12

F.

Fischer, Remarks on Notes on Portland Cement	246
Fitzmaurice, James T., elected Member	1
Frost, H. P., elected Member	37

G.

Greenwood, Remarks on Paper on compressed Air	80
Greenwood, Remarks on Notes on Portland Cement	250

H.

Harris, George A., elected Member	49
Harbour Steamers, our Colonial Built	156
Henson, Remarks on Paper on Compressed Air	80
Henson, J. B., elected Auditor	220
Henson, J. B., Remarks on Notes on Portland Cement	248
Holyhead Breakwater	98
Hydro-Pneumatic Elevator	49

I.

	PAGE
Ice, the Manufacture of	188
Improvements of Rivers	17
Iron *v.* Wood for Bridges	13

J.

Jetties and Breakwaters, on the Construction of	89
Jones, Remarks on Paper on Compressed Air	81
Joy's Valve Gear	214

K.

Kerle, Remarks on Paper on Compressed Air	80
Key's Slide Valve	205
Kopsch, C. F., elected Student	220

L.

Laing, Remarks on Paper on Breakwater	122
Leahy, John A. L., elected Member	1
Leahy, on Simultaneous Telegraphy and Telephony	37
List of Members	xxviii

M.

MacDougall, John, elected Member	21
Mackay, Remarks on Paper on Compressed Air	80
Mackay on Mechanics of Agriculture	149
Manhes Process for Copper Ores	21
Massey, George, elected Member	1
Marseilles Breakwater	99
Madras Breakwater	101
Meat, Transit and Preservation of	17
Mechanics of Agriculture	149
Metallic Arch, the	166
Metallic Permanent Way	13
Mining	14
Mountain, Remarks on Paper on Compressed Air	83
Mountain, Notes on Portland Cement	220
Mountain, Reply to Discussion on Notes on Portland Cement	252

N.

Navigation, Economy in Steam	199
Newhaven Breakwater	107
Nixon, E. S., elected Member	149
Noakes, W. M., elected Member	89
Notes on Portland Cement	220

O.

PAGE
Officers, 1885-86 ... ... xxvii.
Ores, Copper, Treatment of 21

P.

Paisley, Wm., elected Member 89
Park, R. P., elected Member 149
Paving, Street 16
Pardy's Low Pressure Tramway System 49
Permanent Way, Metallic 13
Plymouth Breakwater 94
Pollock, Remarks on Paper on Compressed Air 79
Poole, Remarks on Paper on Compressed Air 80
Poole, Remarks on Paper on Breakwaters 121
Portland Cement, Notes on 220
Portland Cement, Tasmanian 231
Portland Cement, Table of Tests 236
Preface ... ... iii.
President's Address 9

R.

Railways, Our 15
Railway, City 16
Reeks, W., elected Member 220
Rhodes, V., elected Member 149
Ritso, George T., elected Member 49
Rivers, Improvements of 17
Robertson, W. F., elected Member 220
Rules and By-laws, Alteration of section v., clause i. 199, 220
Rules and By-laws ... ... xv.

S.

Scott, Thomas, elected Member 9
Selfe, Norman, on Compressed Air 49
Selfe, Norman, Reply to Discussion on Paper on Compressed Air ... 86
Selfe, H., on Our Colonial-built Harbour Steamers 156
Shellshear, President's Address 9
Shellshear, Remarks on Paper on Compressed Air 85
Shellshear, on Construction of Breakwaters and Training Jetties ... 89
Shellshear, Reply to Discussion on Paper on Breakwaters 132
Shellshear, Remarks on Paper on Portland Cement 251
Simultaneous Telegraphy and Telephony 37
Smail, Remarks on Paper on Portland Cement 242
Soda, on the Use of Concentrated Solution of, for Generating Steam... 135
Specification, Cement 234
Street Paving 16
Steam Navigation, Economy in 199
Strength of Concrete Blocks 230
Sulina Mouth of Danube, Training Jetties 114

T.

PAGE
asmanian Portland Cement 231
Telegraphy and Telephony, Simultaneous System of 37
Touch, John E., elected Member 1
Tramway Propulsion, Comparison of three Systems 70
Triple Expansion Engines 213
Twin Screws in Steamers 212

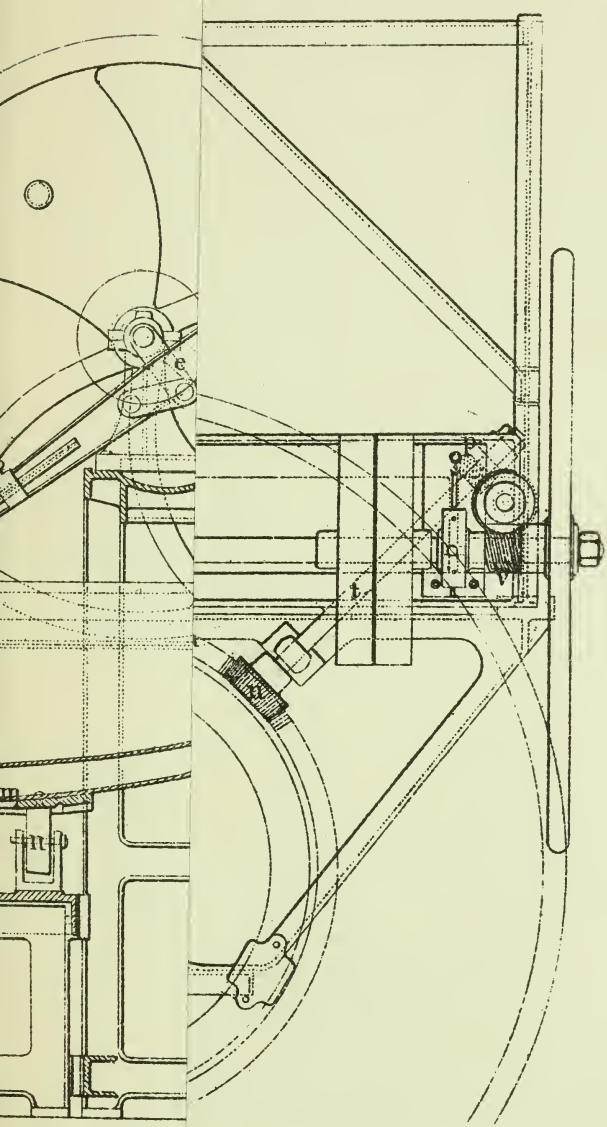
V.

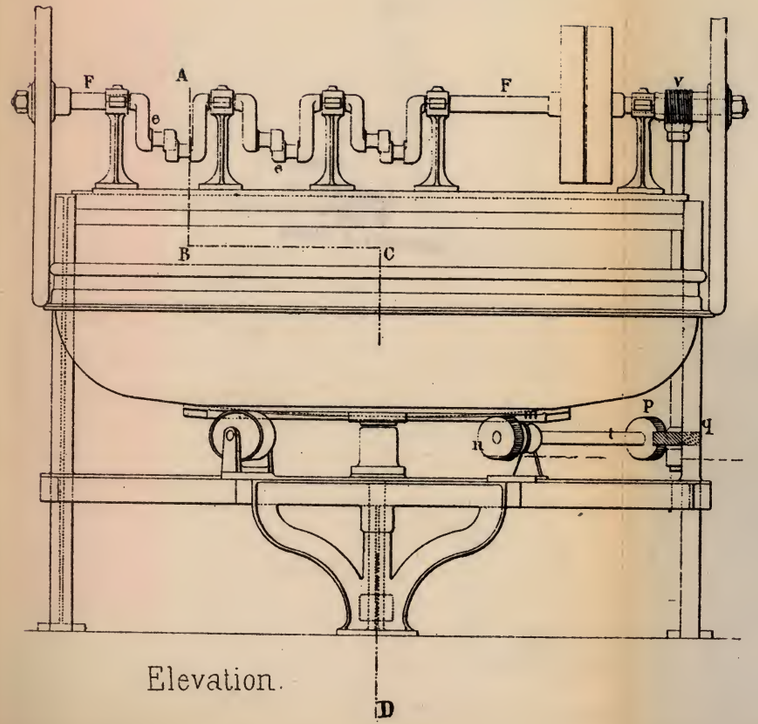
Vale, Hy. T., elected Member 199
Van Rysselberghe's System of Simultaneous Telegraphy and Telephony 37
Van de Velde, Treatment of Copper Ores 21
Van de Velde, Manufacture of Bread 21
Van de Velde, Remarks on Paper on Compressed Air 82

W.

Wagemann on the Use of Concentrated Solution of Soda for Generating Steam 135
Water Conservation 14
Watkins, Charles E., elected Member 49
Warren, Remarks on Paper on Portland Cement... 237
Wicklow Breakwater 108
Wilkinson, C. S., elected Member 220

JAS. MILLER & CO., Machine Printers, 78 Clarence-street, Sydney.

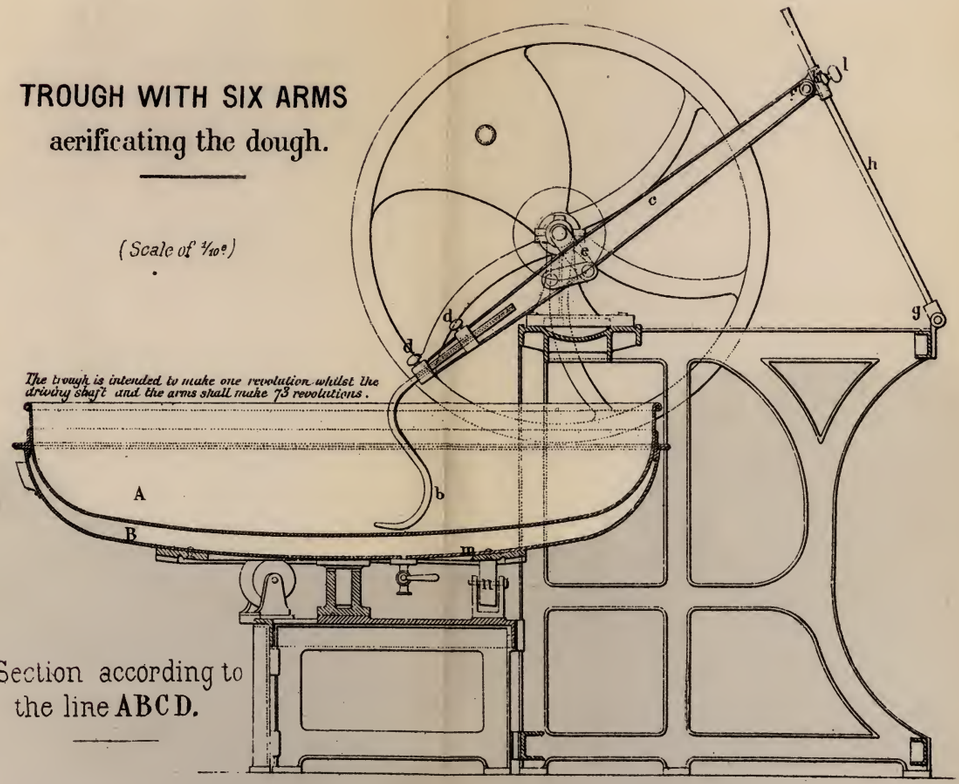

e
t



Elevation.

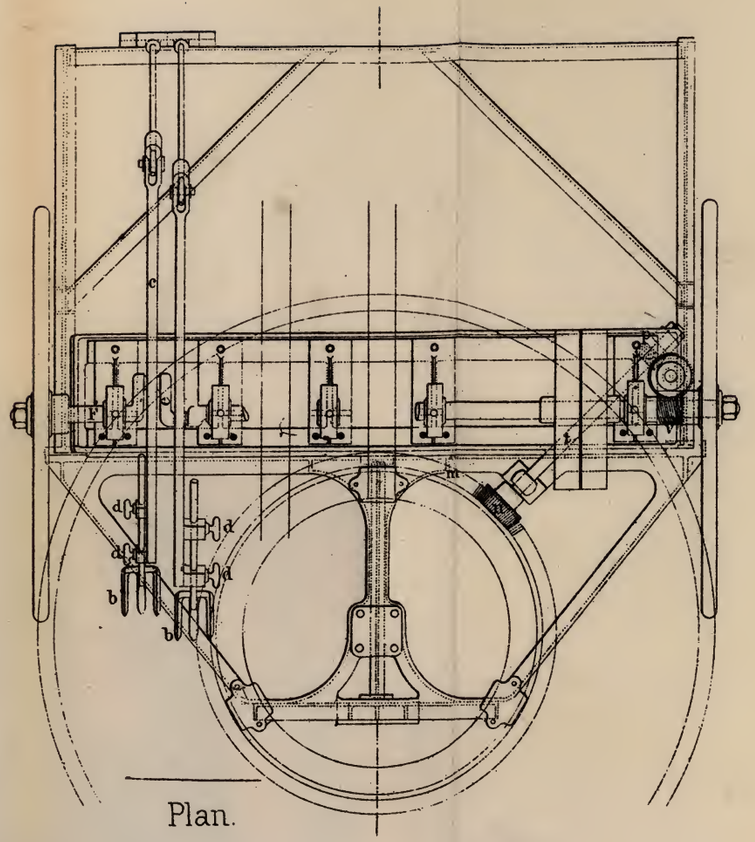
TROUGH WITH SIX ARMS
aerificating the dough.

(Scale of 1/10e)



The trough is intended to make one revolution whilst the driving shaft and the arms shall make 73 revolutions.

Section according to the line **ABCD.**



Plan.

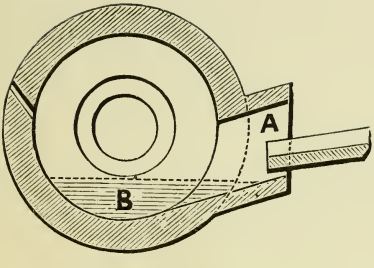


Fig.1.

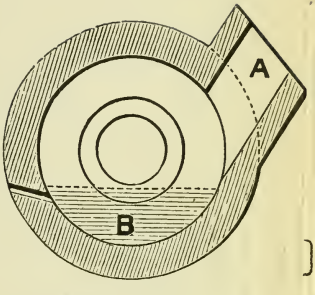


Fig.3.

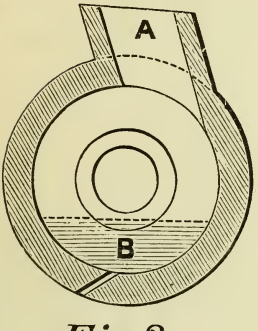
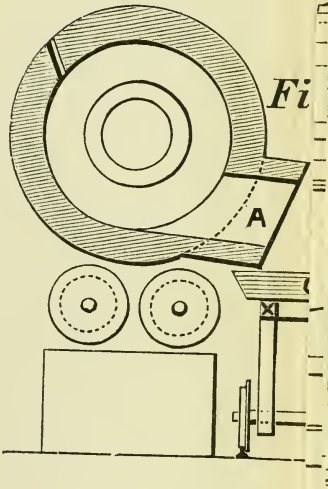


Fig.2.



Fi

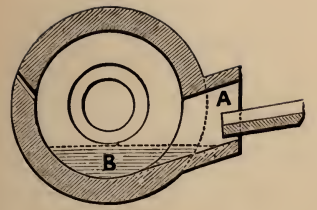


Fig.1.

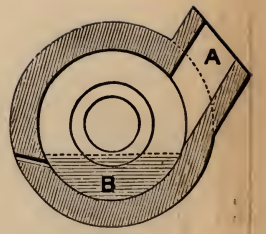


Fig.3.

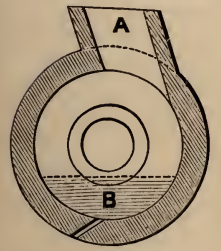


Fig.2.

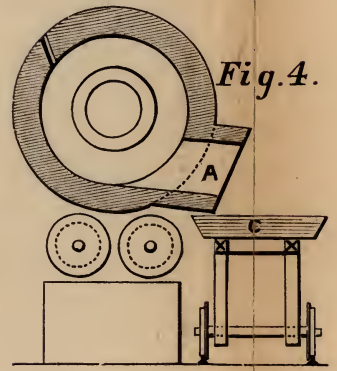


Fig.4.

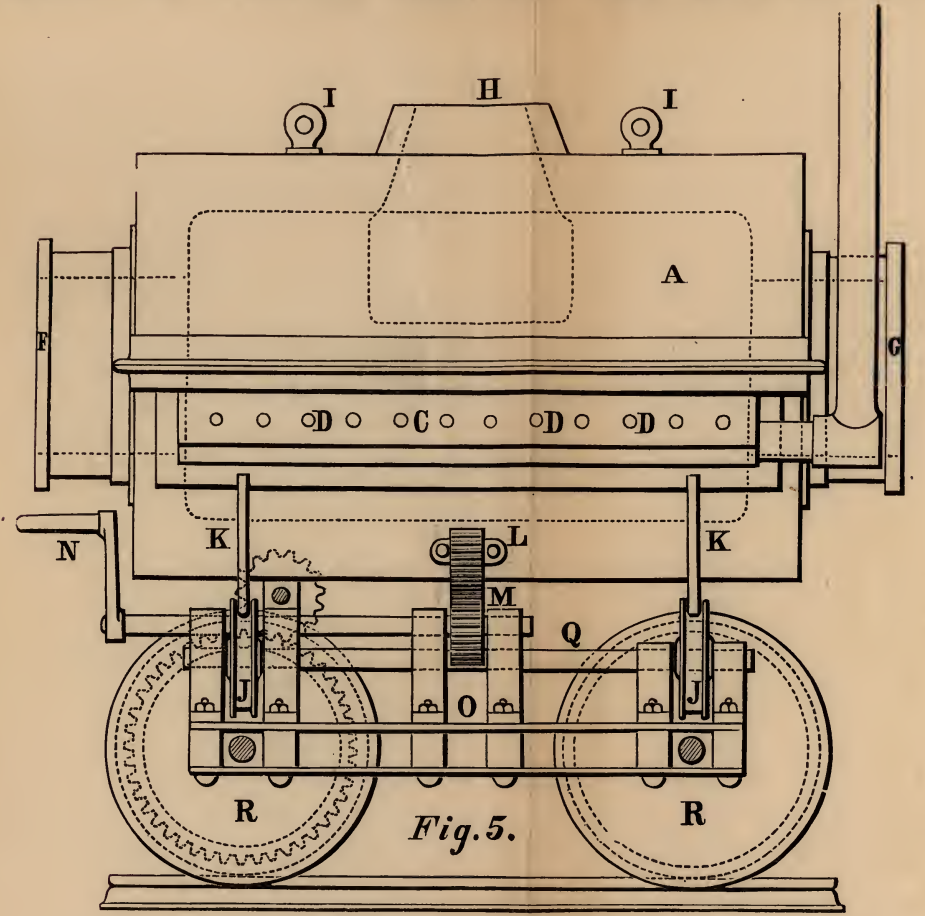


Fig.5.

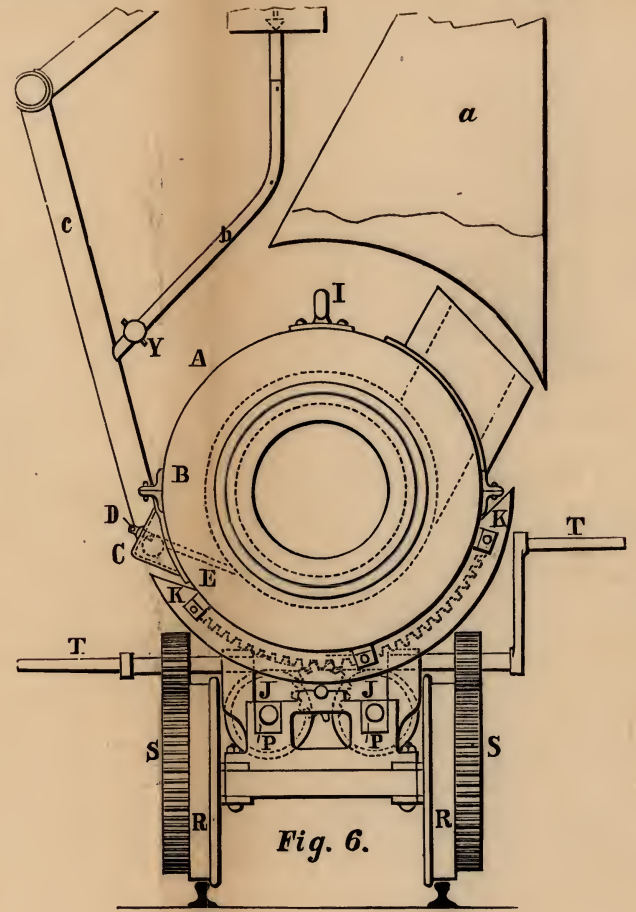
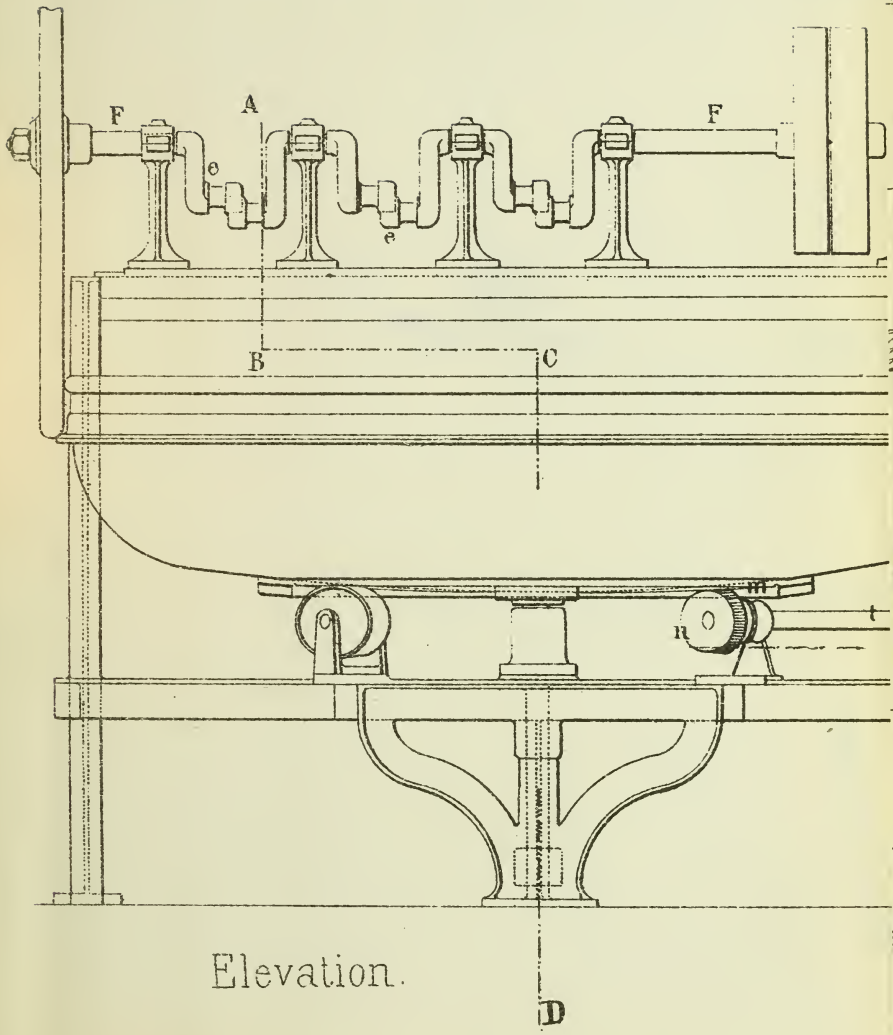


Fig. 6.

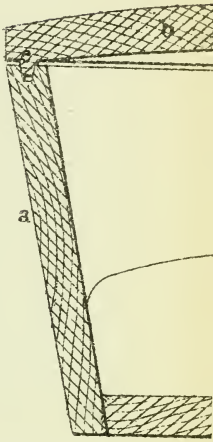


Elevation.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

MANUFACTURE OF BREAD

VESSEL FOR THE PR

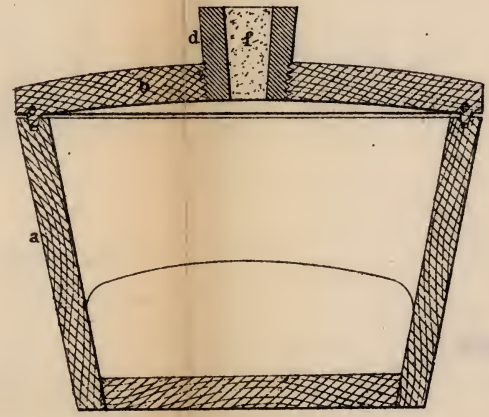


VESSEL FOR THE

MANUFACTURE OF BREAD BY THE DATHIS PROCESS.

Fig.1.

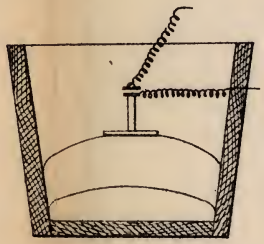
VESSEL FOR THE PRESERVATION OF THE LEAVEN.



Variable scale.

Fig.2.

VESSEL FOR THE FERMENTATION OF THE DOUGH.



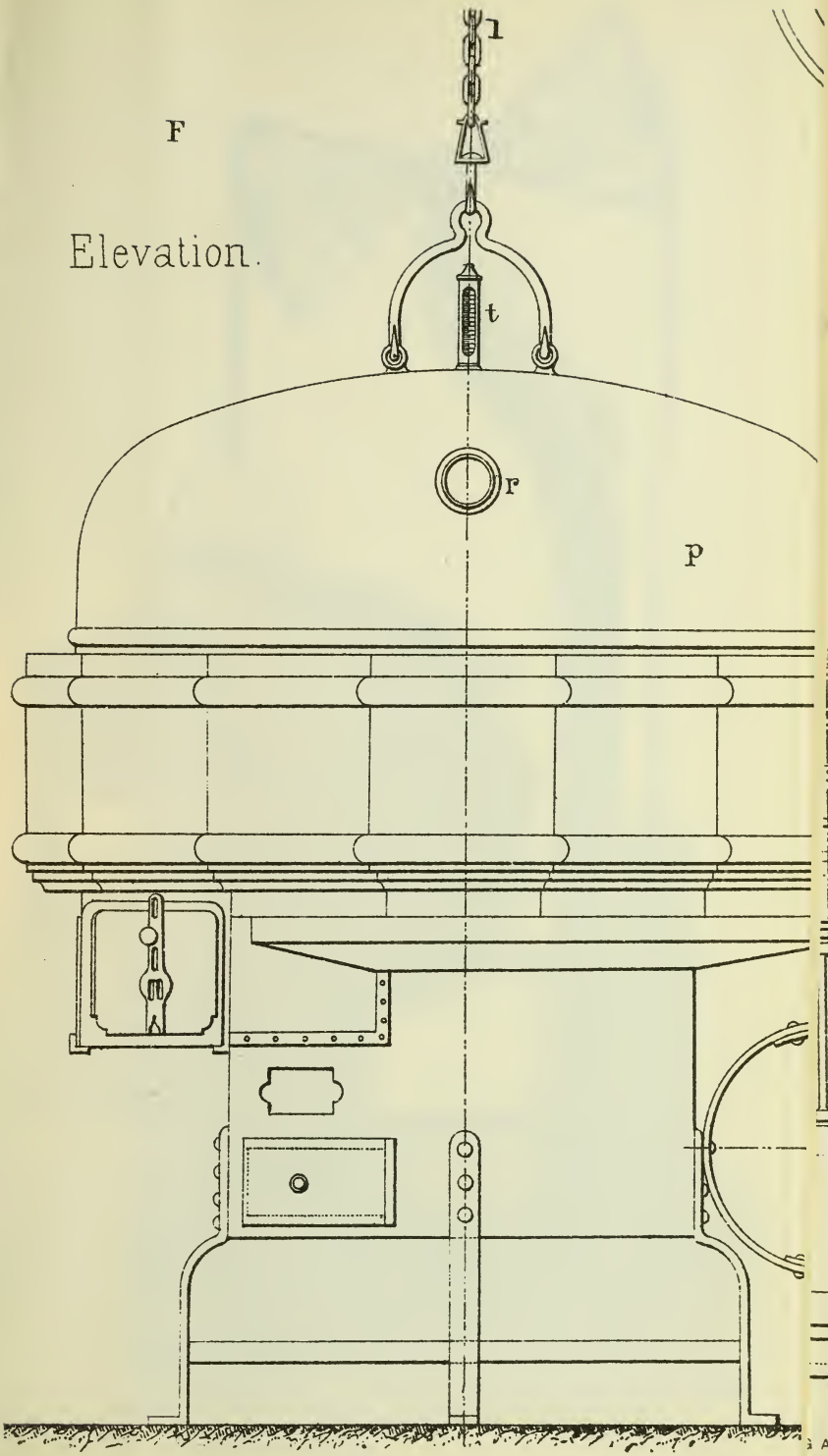

F
Elevation.
l
t
r
p

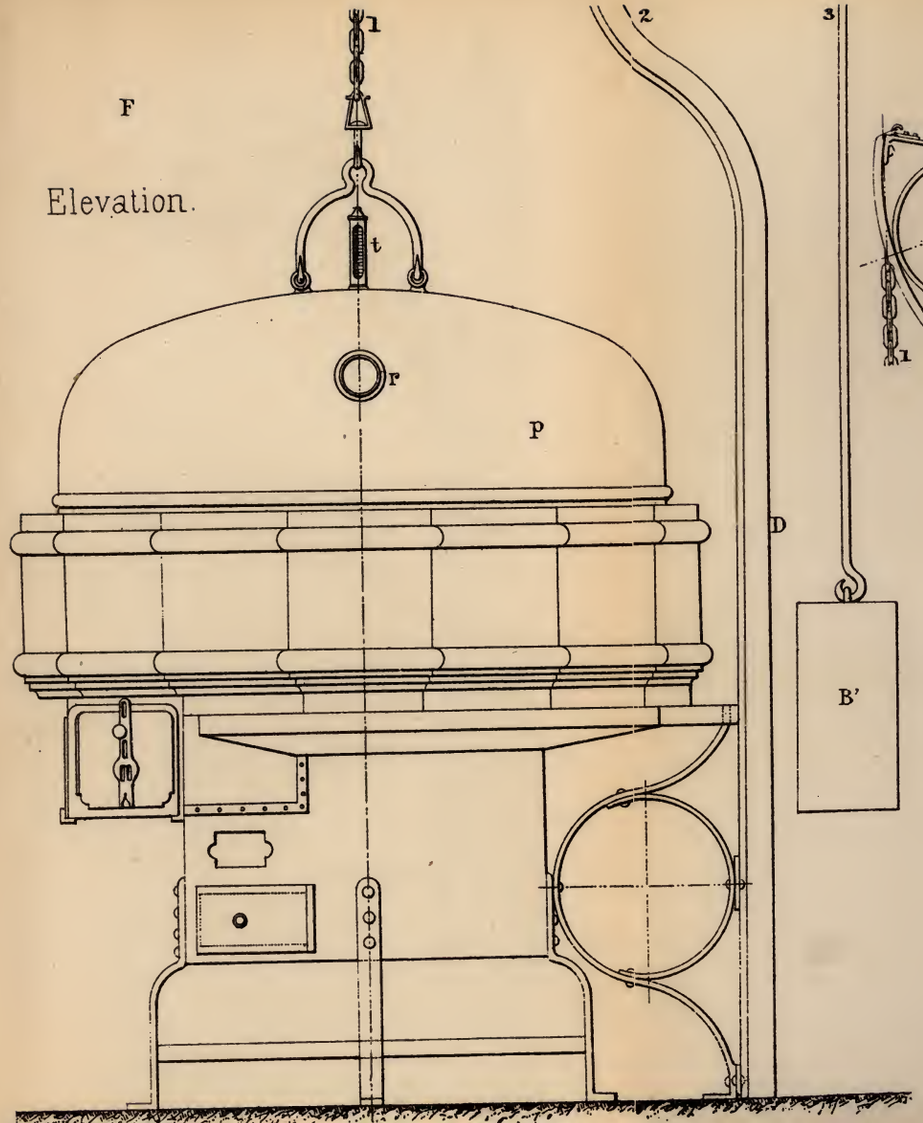
PLATE 4.

MANUFACTURE OF BREAD BY THE DATHIS PROCESS.

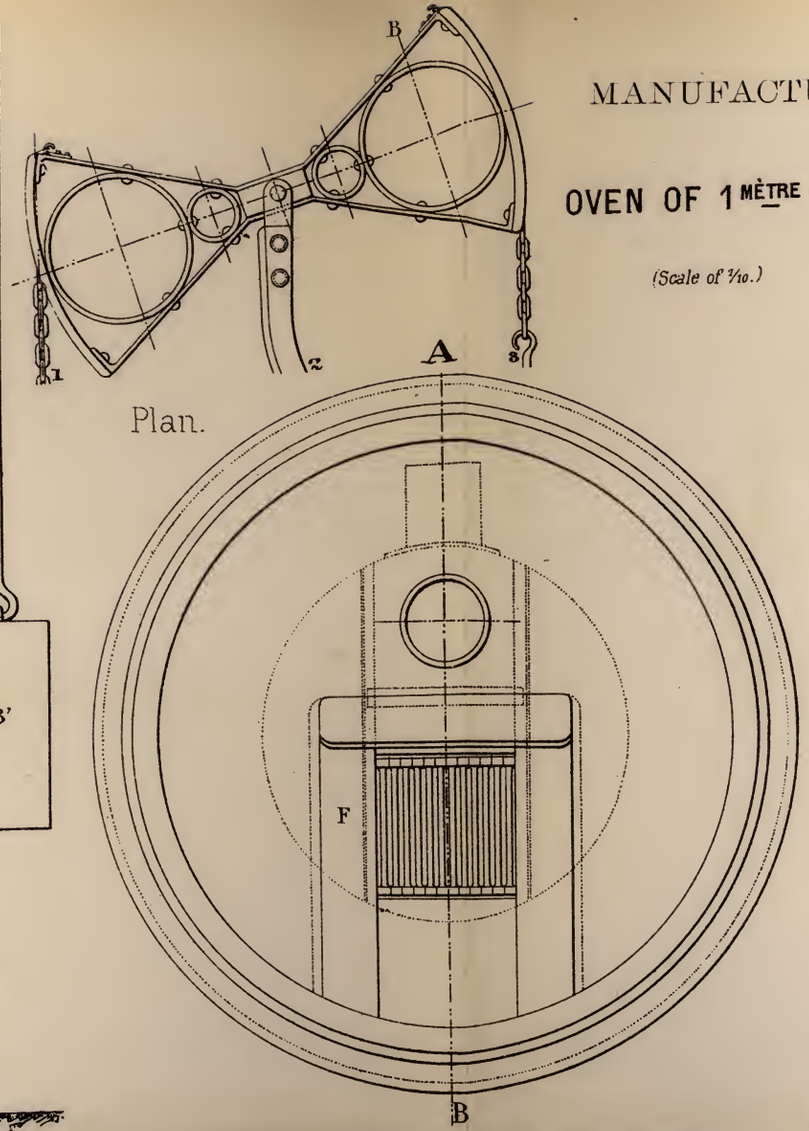
OVEN OF 1 MÈTRE

(Scale of 1/10.)

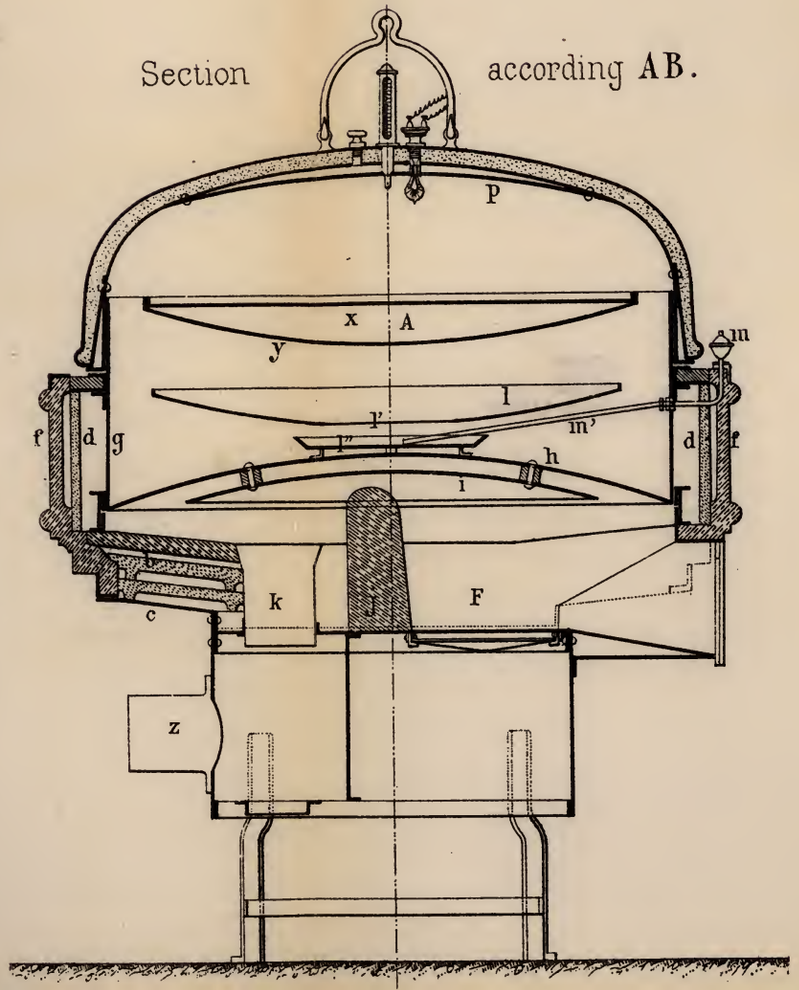
Elevation.

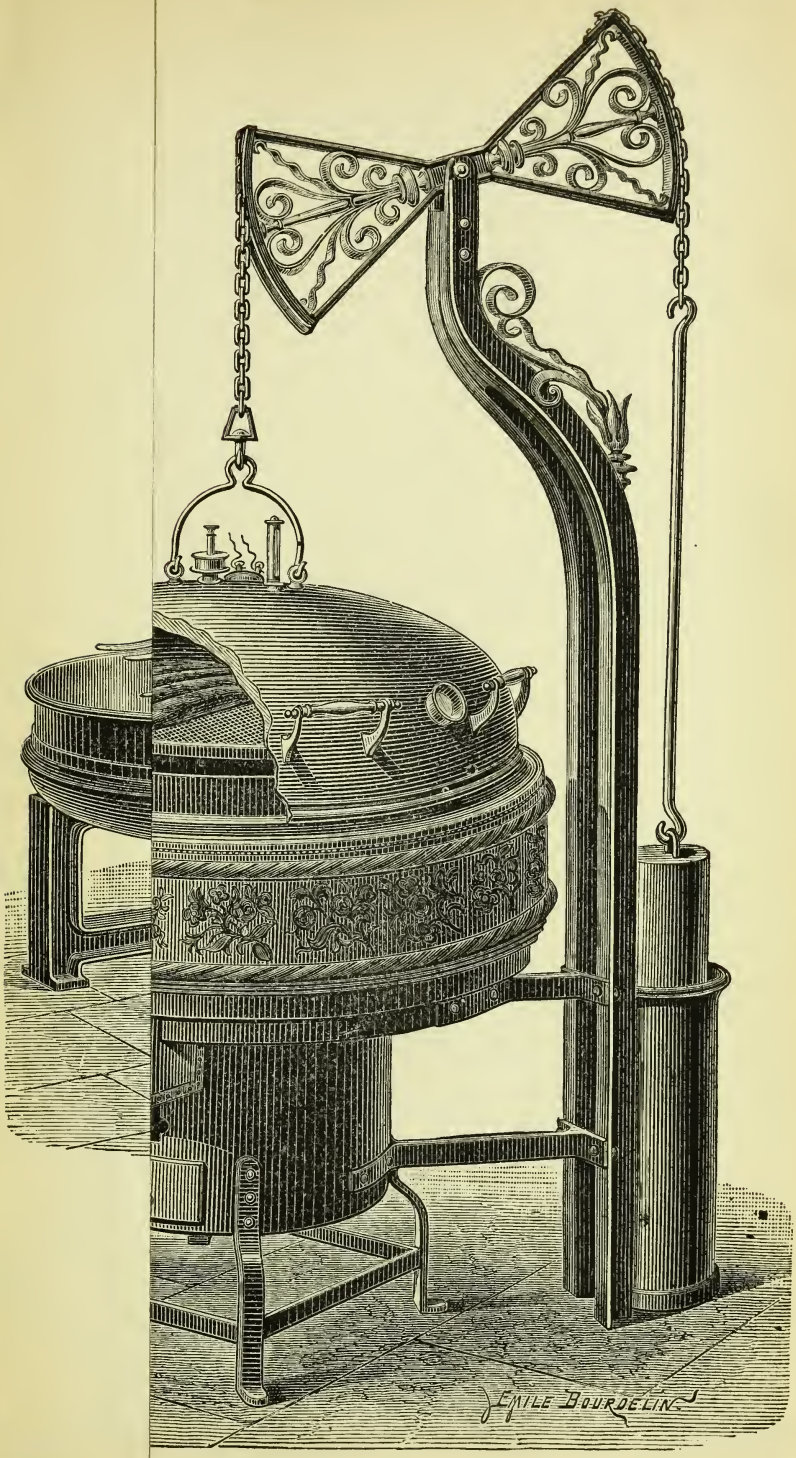


Plan.



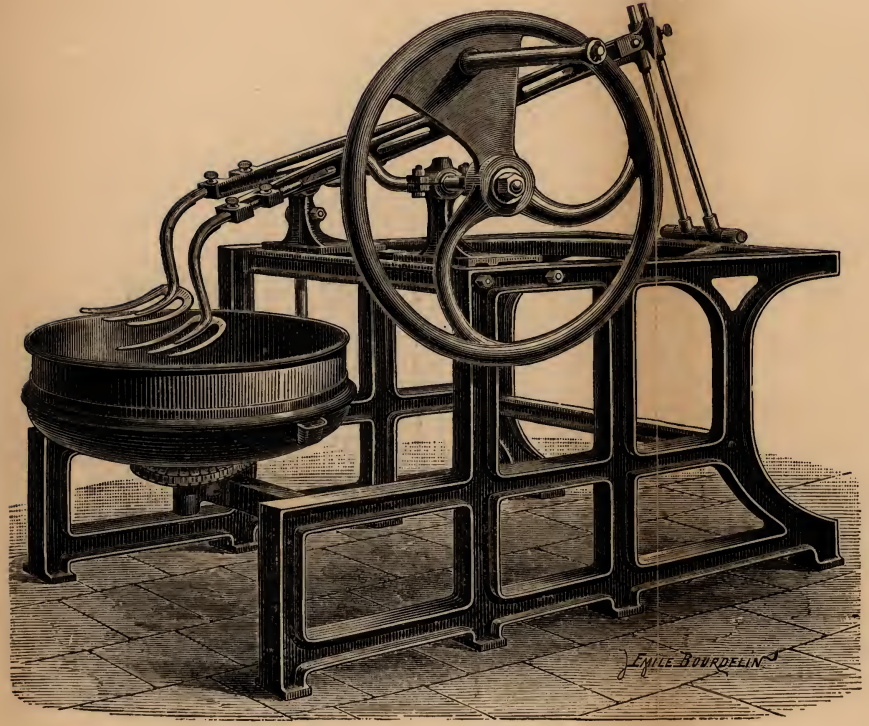
Section according AB.





DATHIS OVEN.

MANUFACTURE OF BREAD BY THE DATHIS PROCESS.



DATHIS KNEADER.

DATHIS OVEN.

SI

Fig. 5.

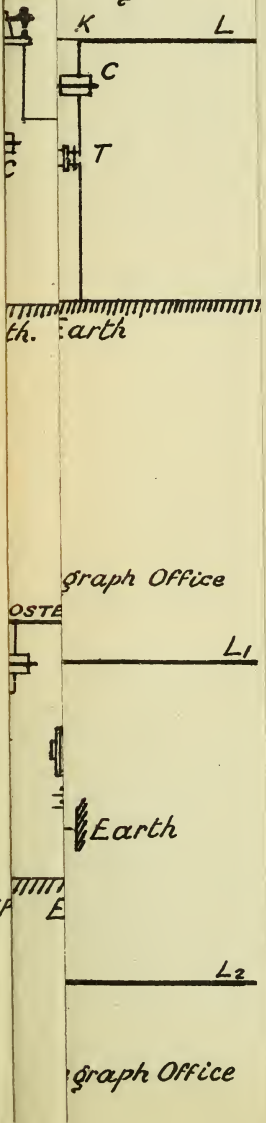


Fig. 1.

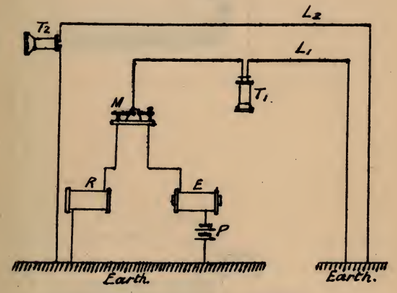


Fig. 2.

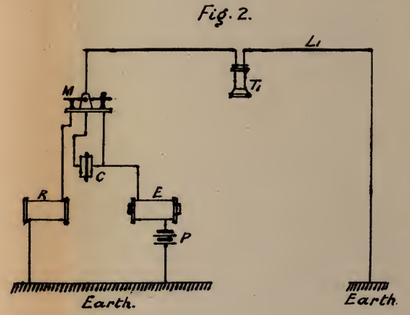


Fig. 3.

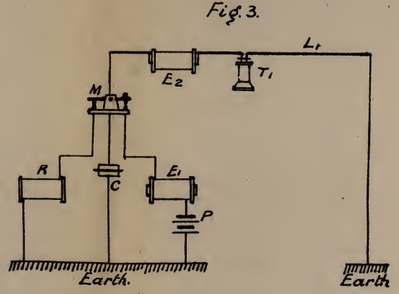


Fig. 4.

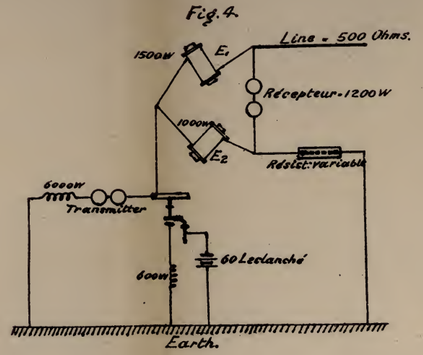
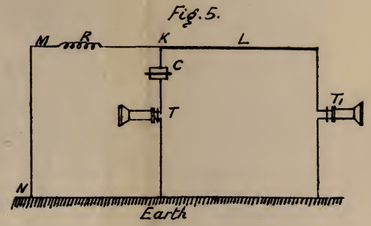


Fig. 5.



Second Solution. Fig. 9.

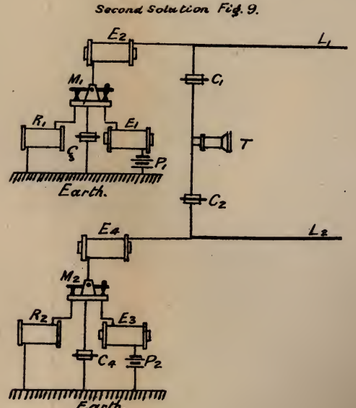


Fig. 6.

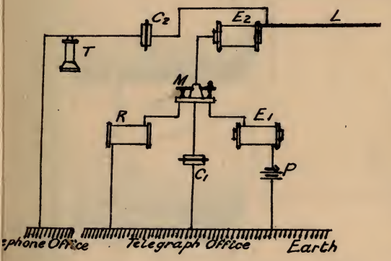
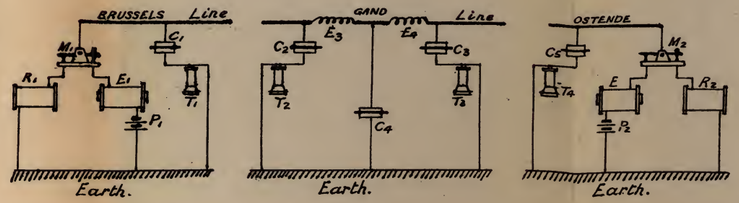


Fig. 7.



First solution. Fig. 8

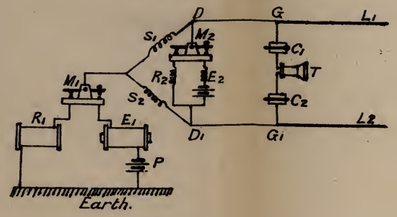
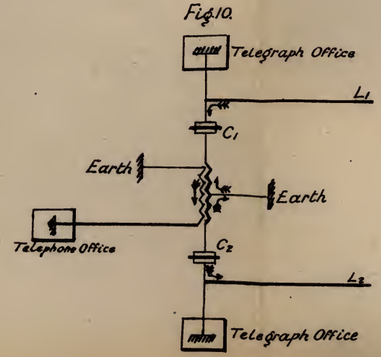
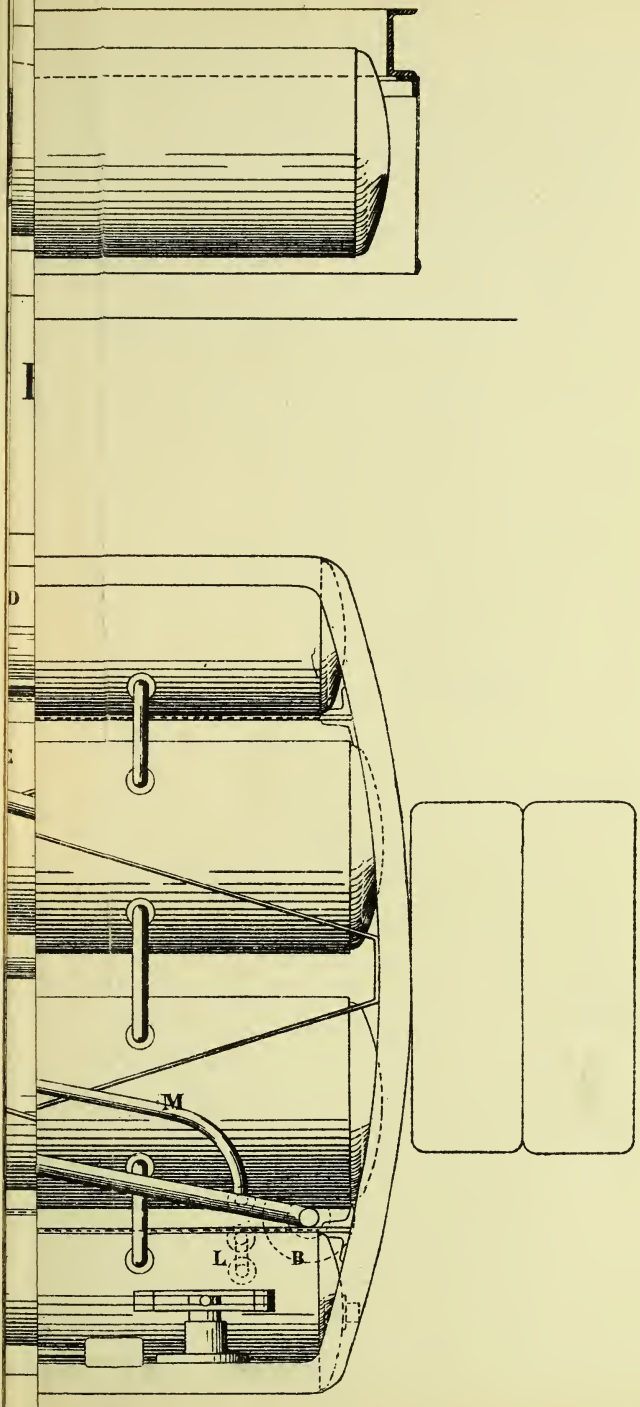


Fig. 10.



COMP



COMPRESSED AIR & ITS APPLICATIONS.

NORMAN SELFE, M.I.C.E., M.I.M.E., &c.,
MEMBER.

PLATE 1.

Fig. 1.

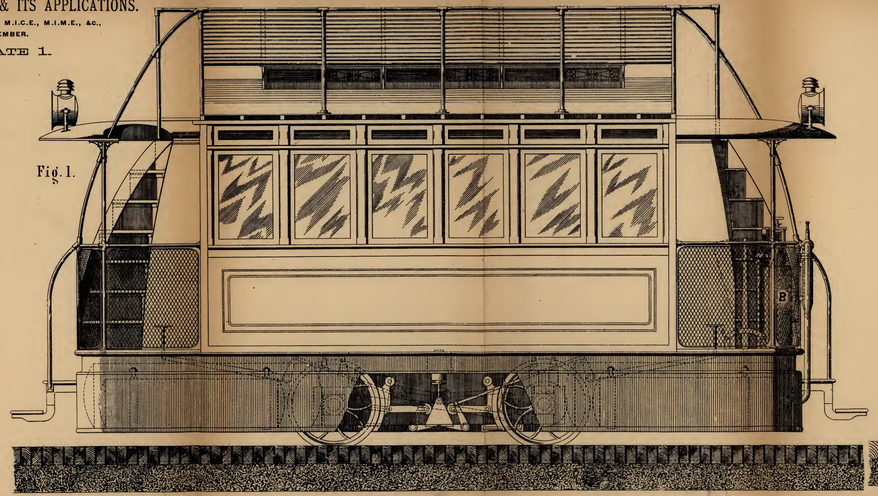
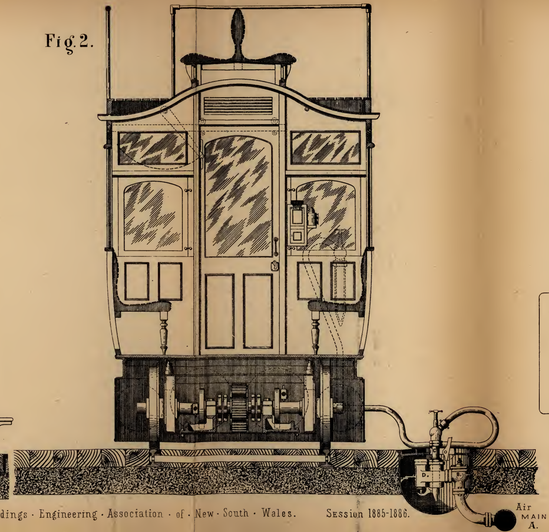


Fig. 2.



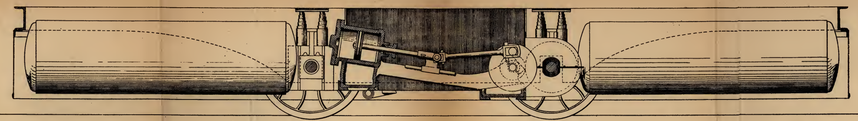


Fig. 3.

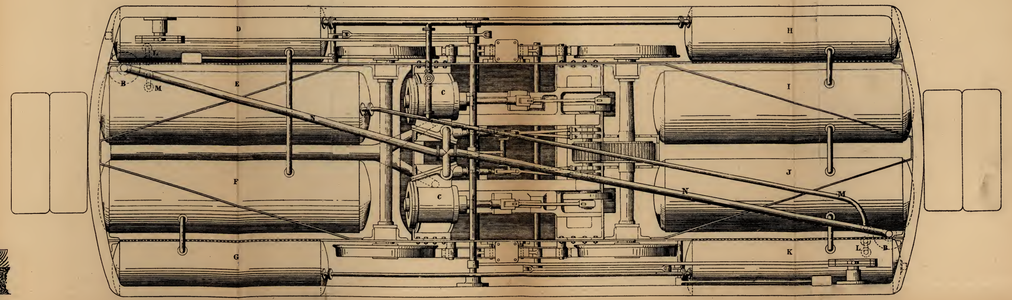
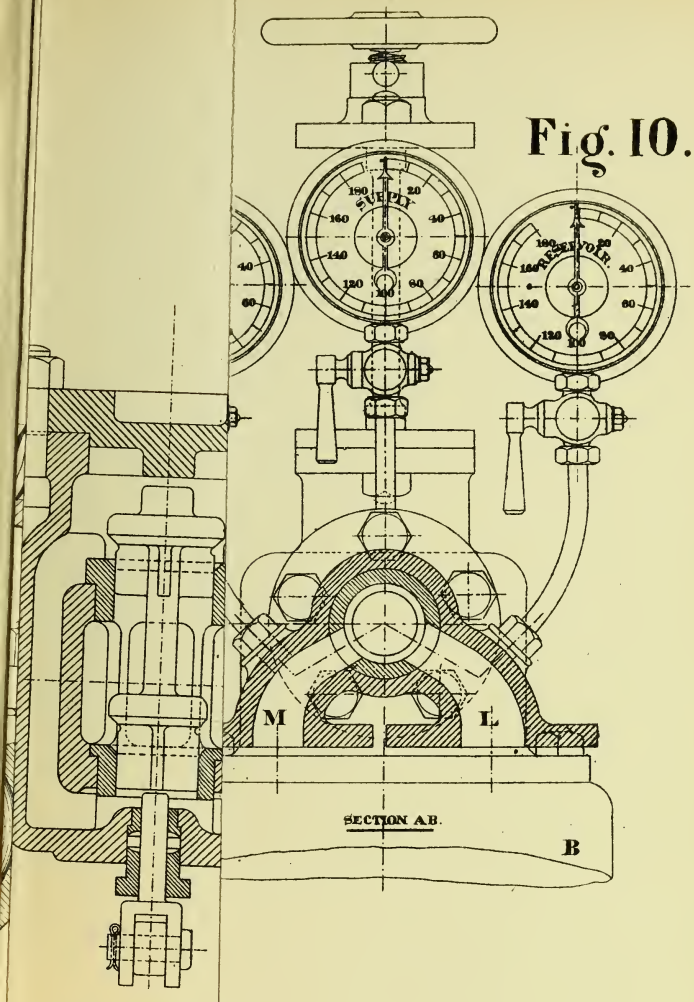


Fig. 10.



SECTION THROUGH A.
on Fig. 8.

PLATE 2.

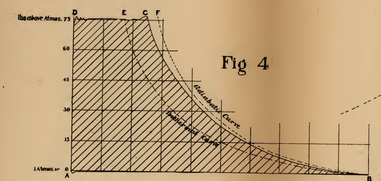
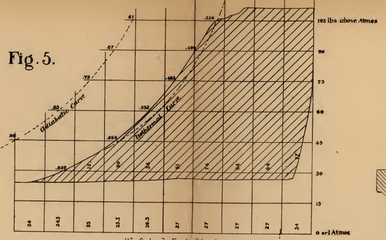


Fig 4

DIAGRAM
from
a Sommeiller Compressor with Hydraulic Piston

Fig. 5.



DIAGRAMS
from
M.r Selfe's Compound Compressor.

Fig. 6.

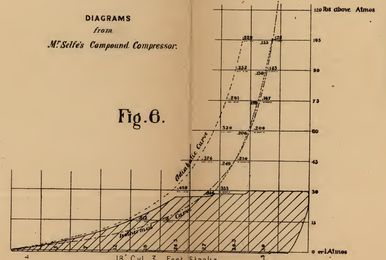
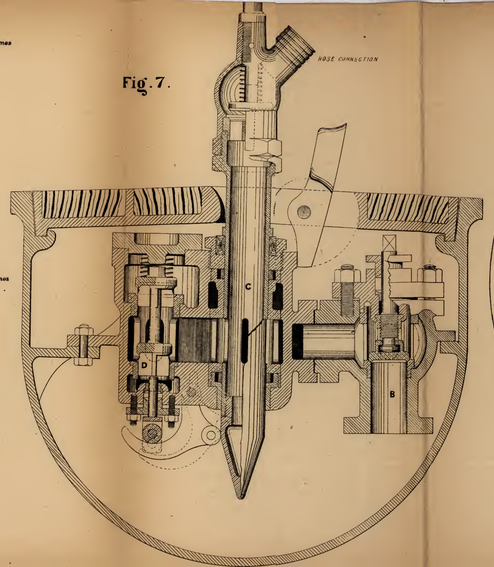


Fig. 7.



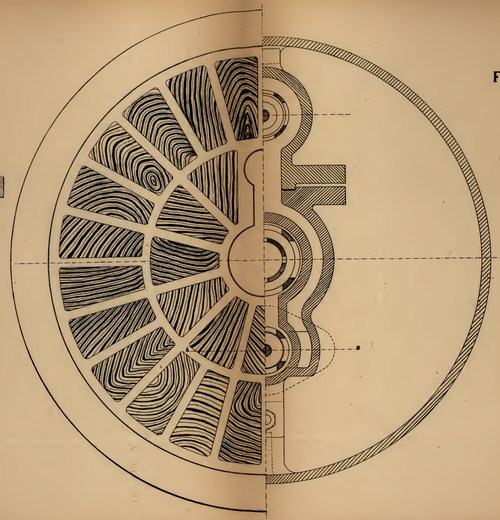
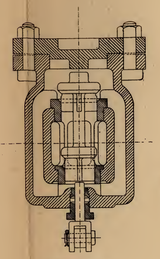
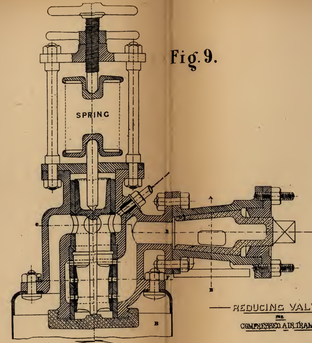


Fig. 8.



SECTION THROUGH A. B. on Fig. 8.

Fig. 9.



REDUCING VALVE
fig.
COMPRESSED AIR TRAMWAYS.

Fig. 10.

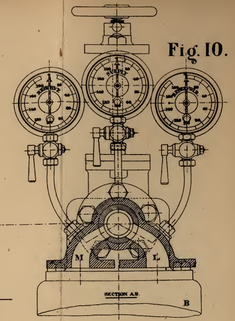


Fig. II.

FROM HUNTER ST TO NEWTOWN.
CLAY ST
PRESIDIO
HAIGHT ST
HORIZONTAL SCALE IN FEET
VERTICAL SCALE IN FEET

NORMAN SELFE, M.I.C.E., M.I.M.E., &c.,
MEMBER.

PLATE 3.

The Hydro-Pneumatic ELEVATOR.

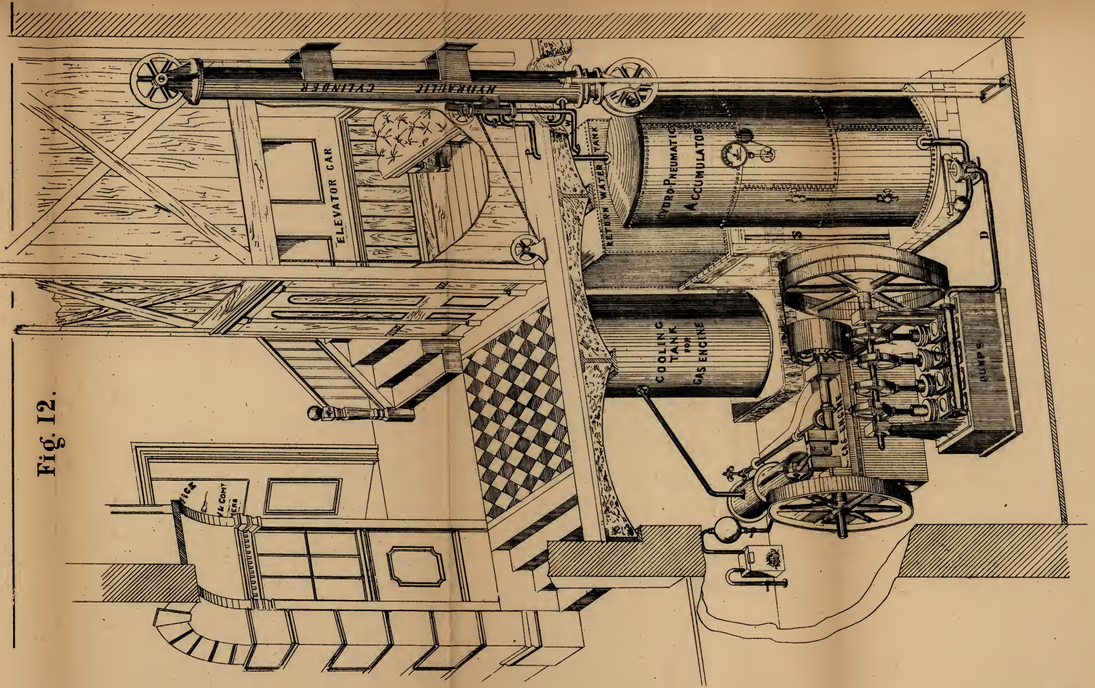


Fig. 12.

SECTION OF PRINCIPAL TRAM-ROADS
SYDNEY.

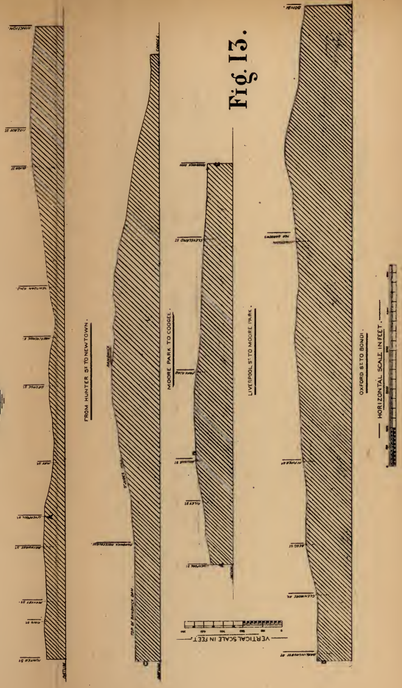


Fig. 13.

SECTION OF PRINCIPAL CABLE ROADS SAN FRANCISCO CALIFORNIA.

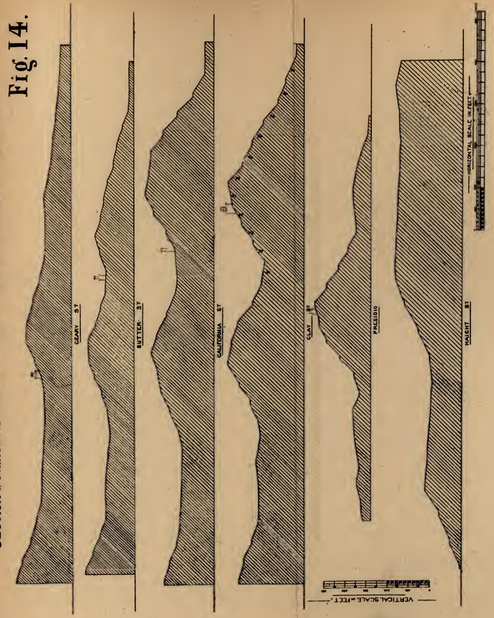


Fig. 14.

T

Sea F

SOCIAT

BREAKWATERS AND TRAINING JETTIES.

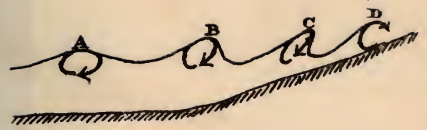


Fig.1.

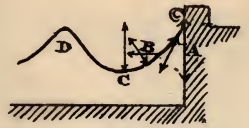
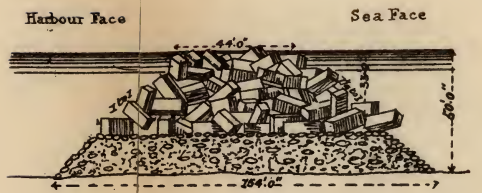
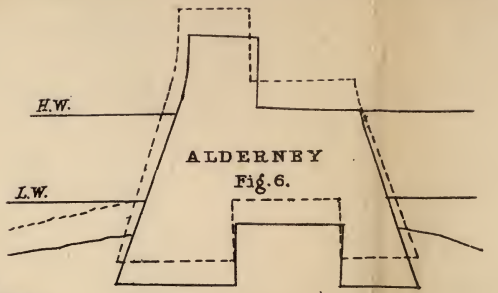


Fig.2.

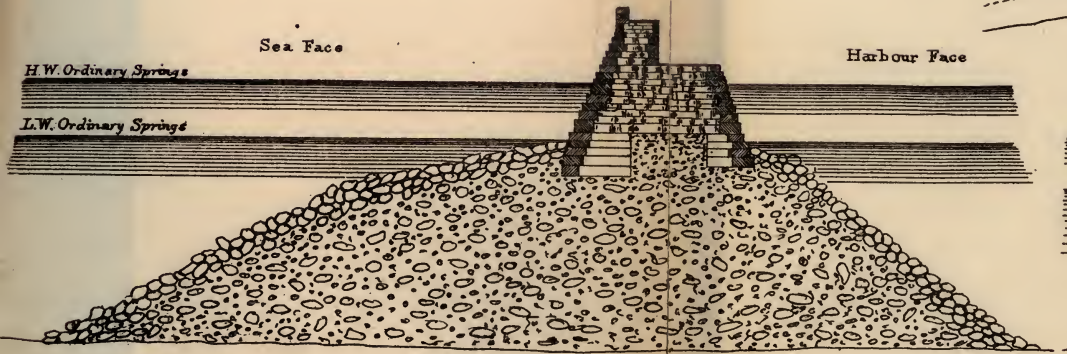
PLYMOUTH
Fig.3.

ALGIERS
Fig.4.

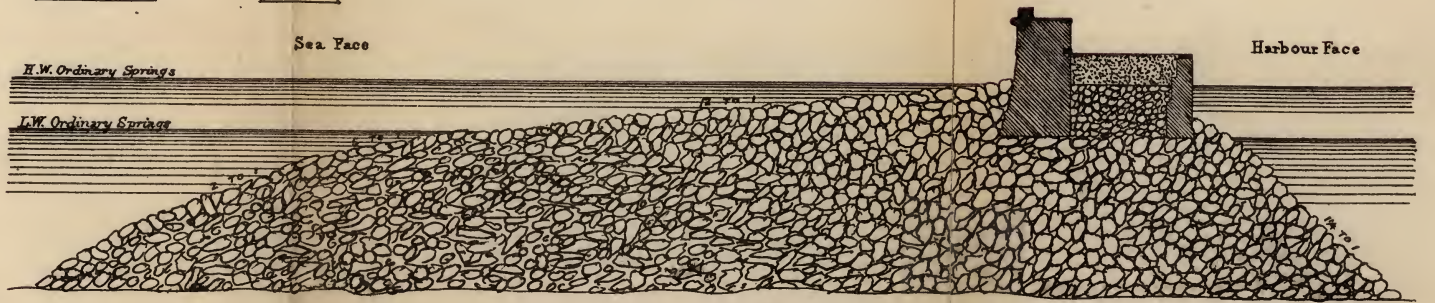




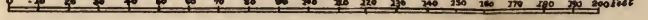
ALDERNEY
Fig.5.



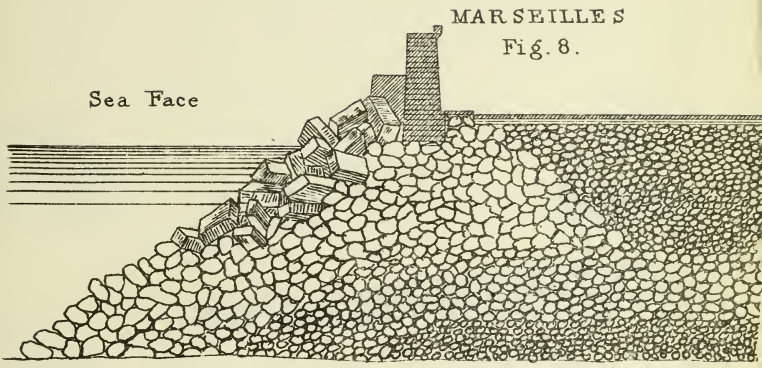
HOLYHEAD
Fig.7.

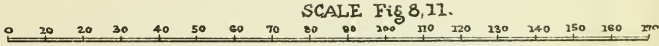


SCALE-FIG3,5,7.

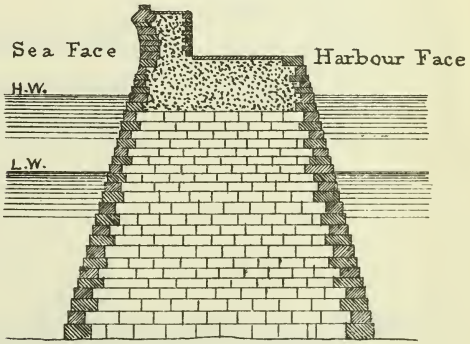


MARSEILLES
Fig. 8.



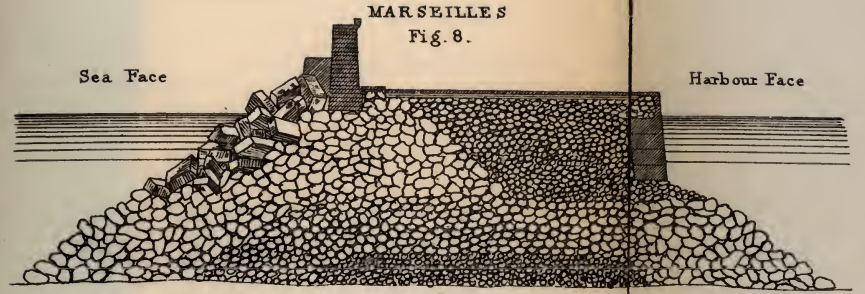


DOVER
Fig. 11.

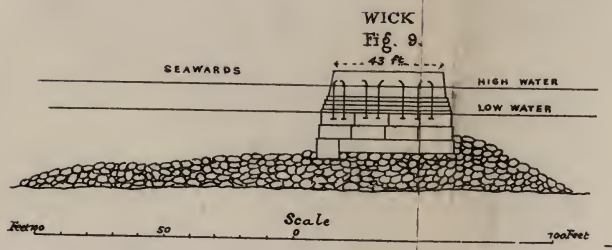


BREAKWATERS AND TRAINING JETTIES.

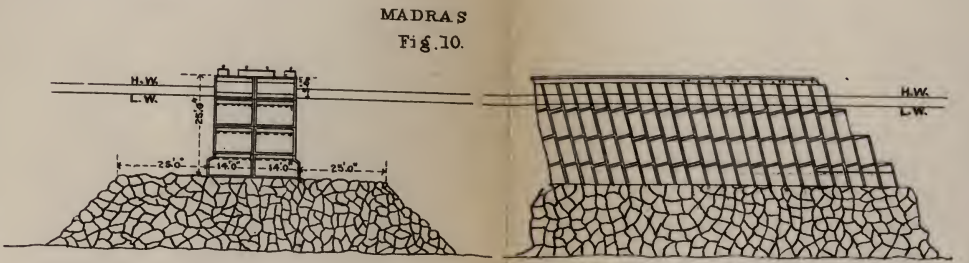
MARSEILLES
Fig. 8.



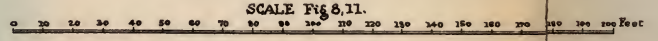
WICK
Fig. 9.



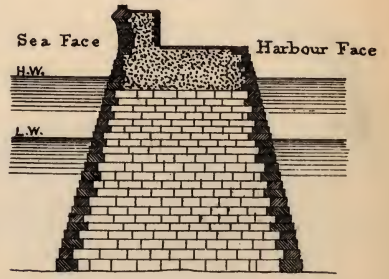
MADRAS
Fig. 10.



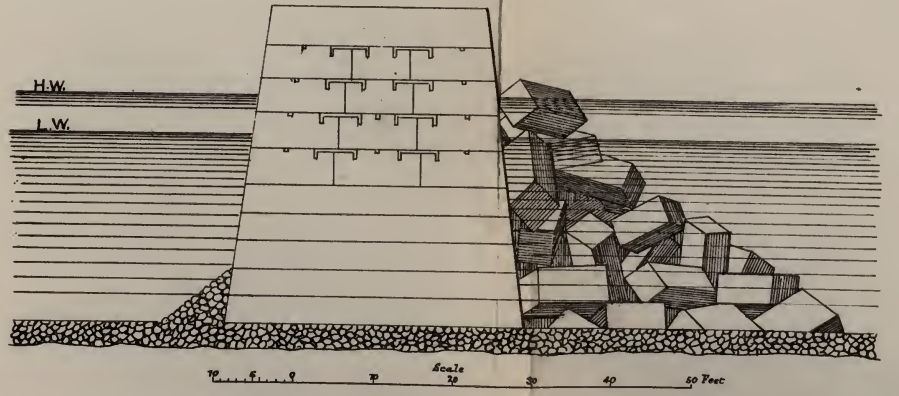
SCALE Fig 8,11.



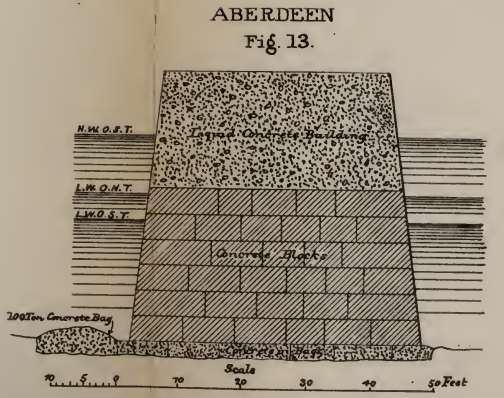
DOVER
Fig. 11.



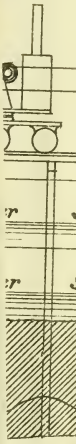
AMSTERDAM
Fig. 12.

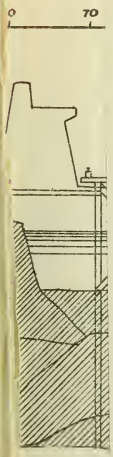


ABERDEEN
Fig. 13.



NING





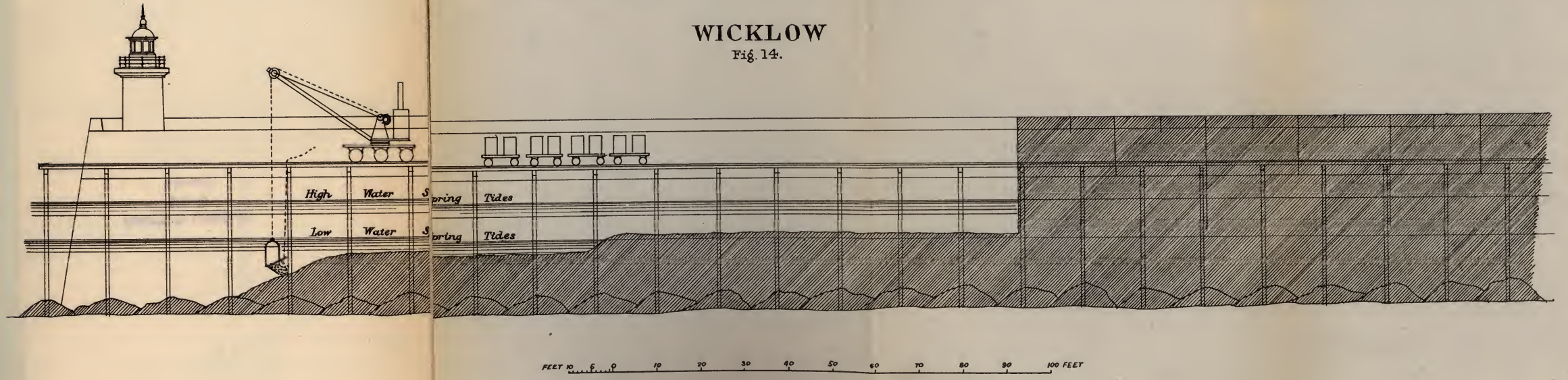
4

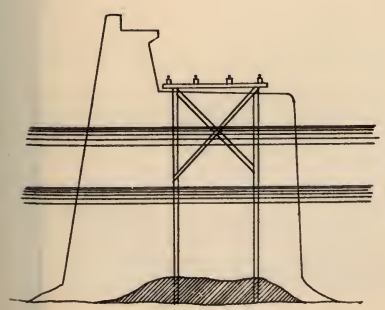
SESSION 18

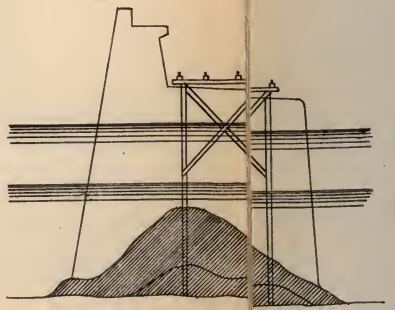
BREAKWATERS AND TRAINING JETTIES.

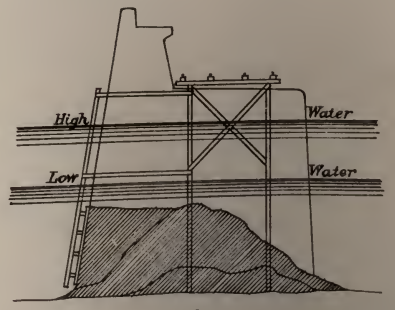
WICKLOW

Fig. 14.

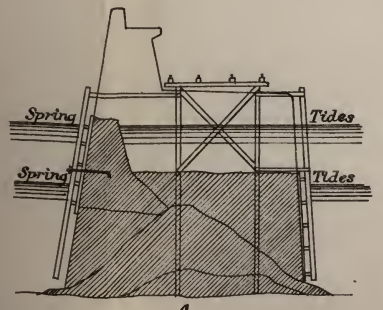



1.

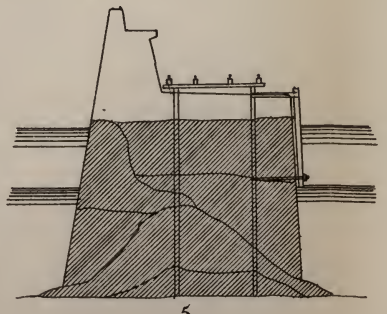

2.

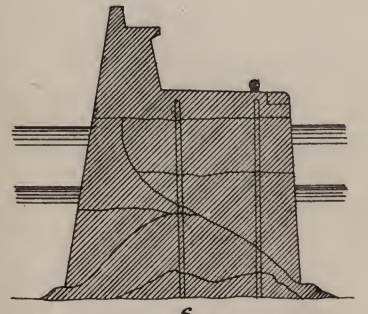


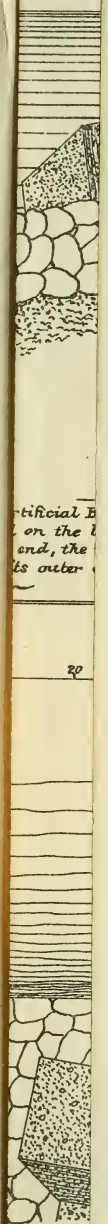
3.



4.


5.


6.



tificial B
on the l
end, the
its outer

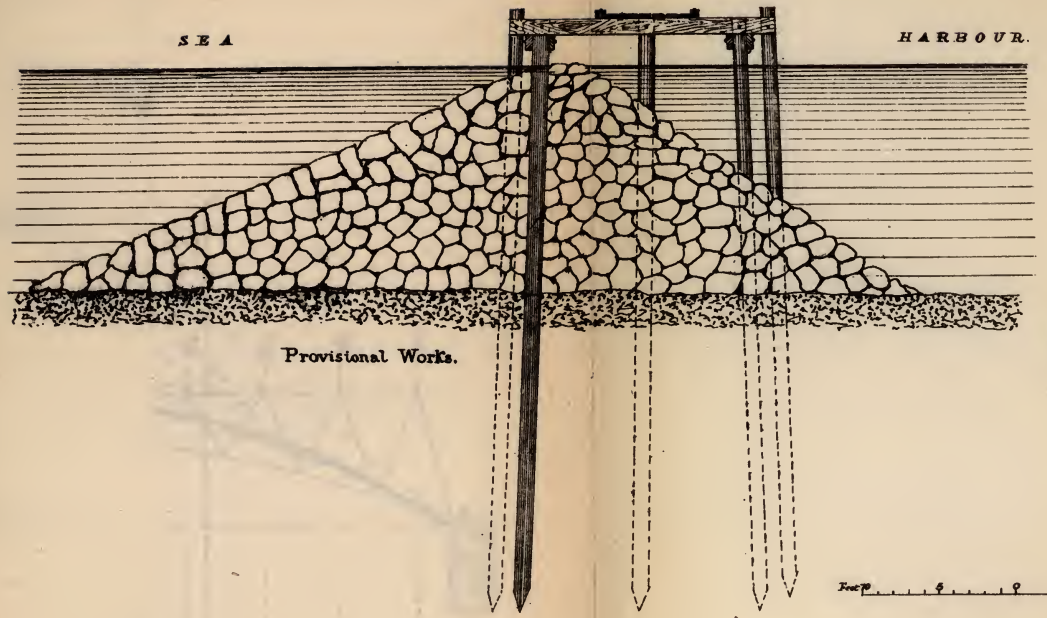
20

85-86.

BREAKWATERS AND TRAINING JETTIES.

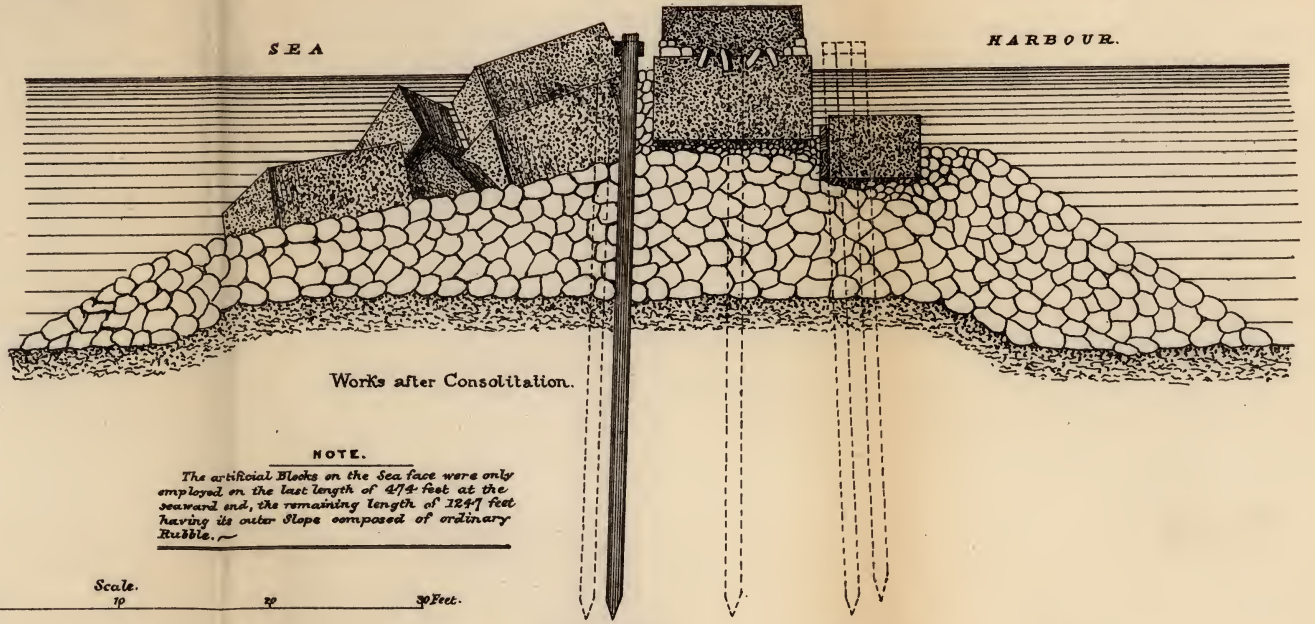
DANUBE.

Fig: 16.



Provisional Works.

Fig: 17.



Works after Consolitation.

NOTE.

The artificial Blocks on the Sea face were only employed on the last length of 474 feet at the seaward end, the remaining length of 1247 feet having its outer Slope composed of ordinary Rubble.

Scale.

Feet 0 5 10 20 30 Feet.

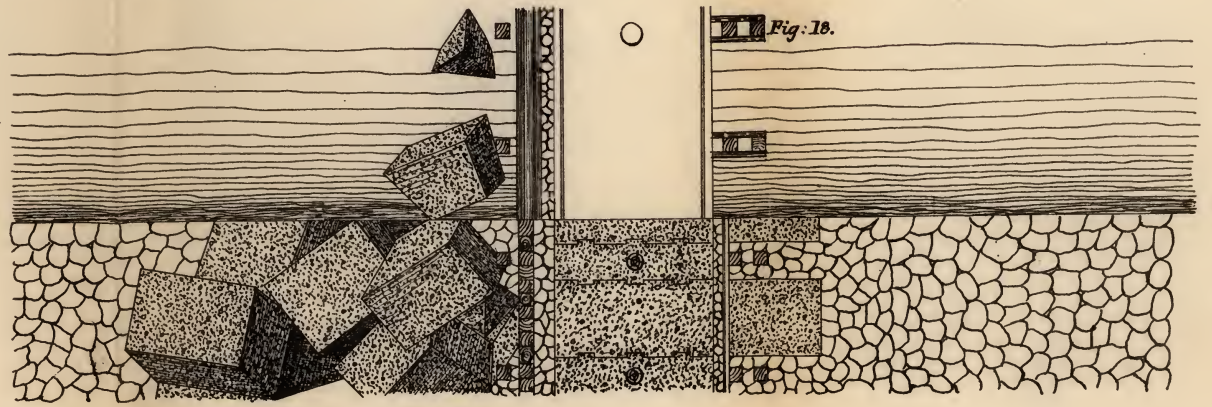
CHARLESTON

Fig. 15.

Scale.

0 5 10 20 30 40 60

Fig: 18.



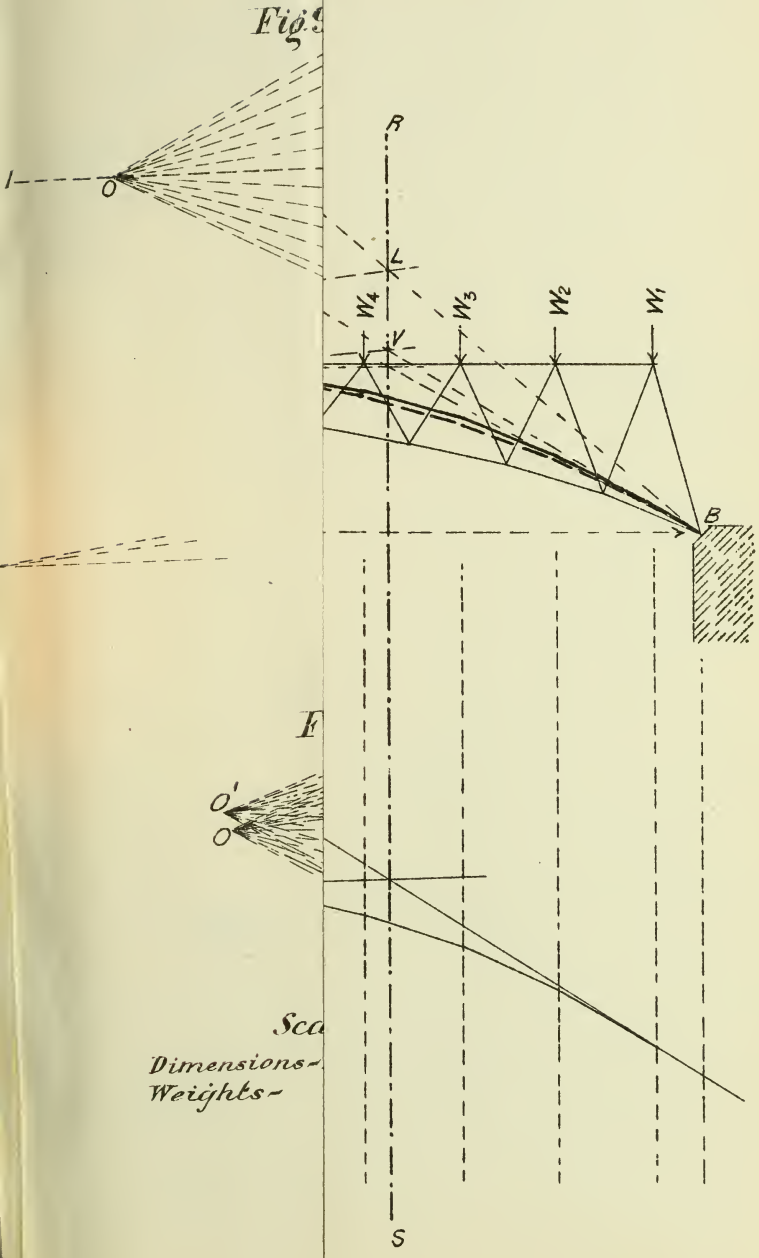


Fig. 3

Fig. 4

Scale

Dimensions-

Weights-

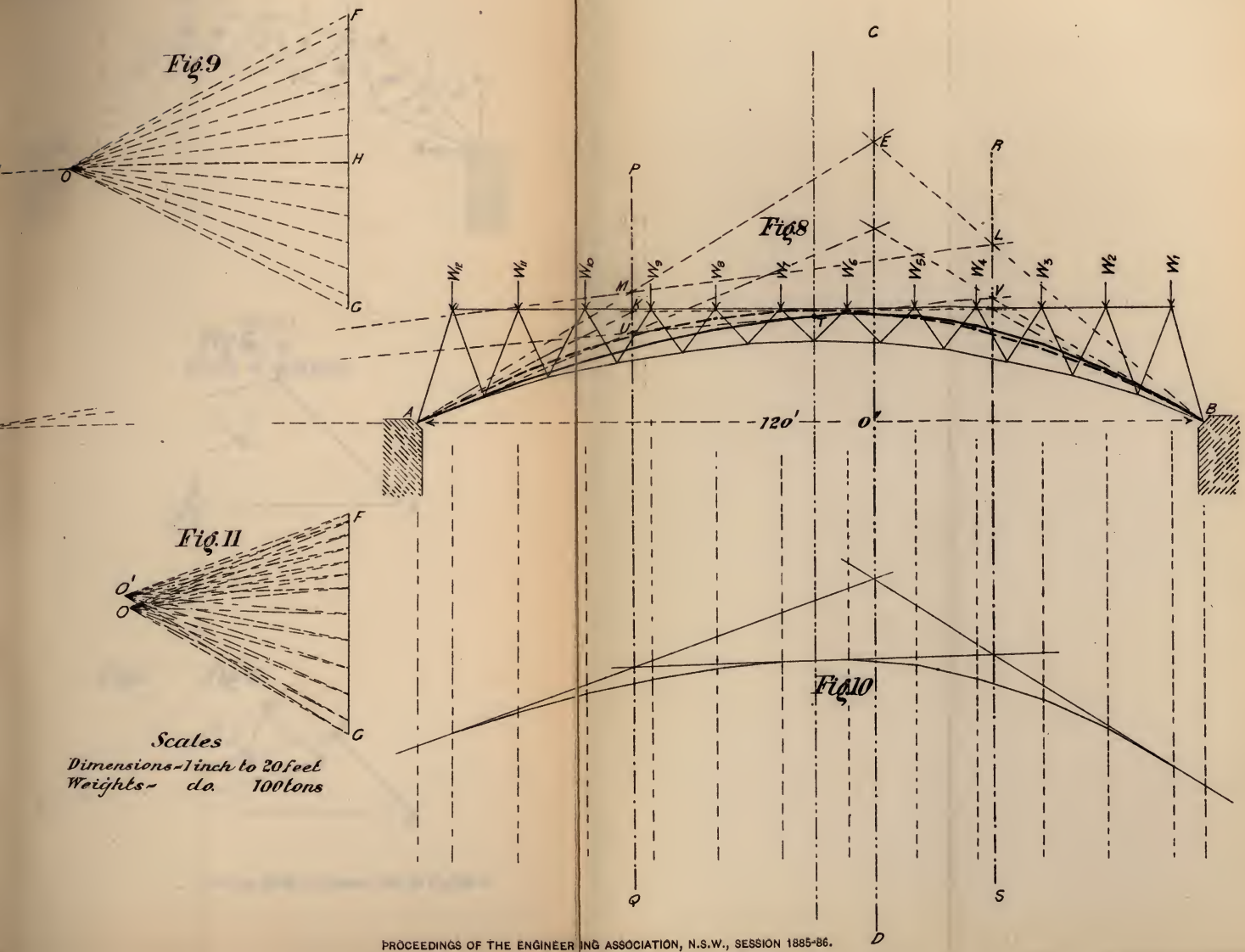
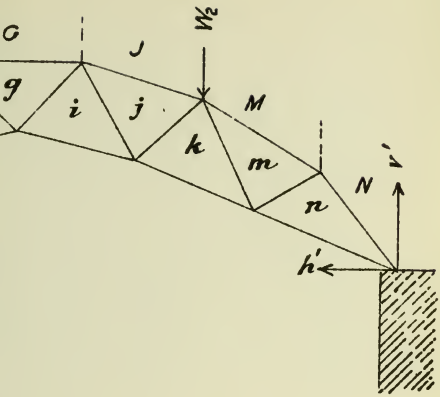
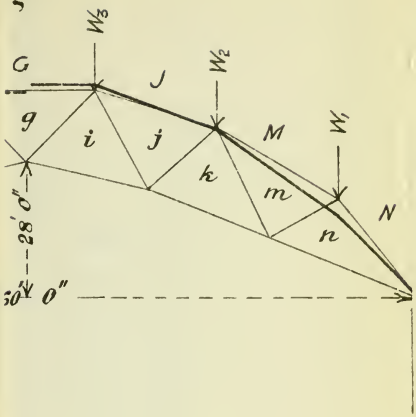


Fig.9
F
H
O
G
C
E
R
P
Fig.8
W12
W11
W10
W9
W8
W7
W6
W5
W4
W3
W2
W1
M
K
L
V
U
T
A
120'
O'
B
Fig.11
F
O'
O
G
Scales
Dimensions-1 inch to 20 feet
Weights- do. 100 tons
Fig.10
Q
S
D

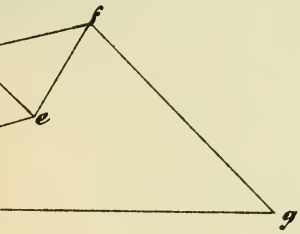
ig.4



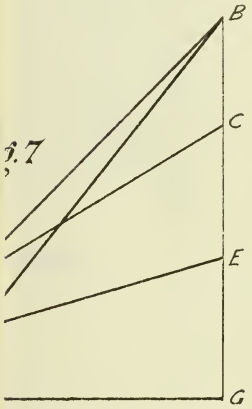
ig.1



ig.5

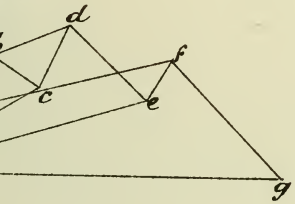


ig.7



Dimen.
Weights(
do. (
da (
do. (

ig.6



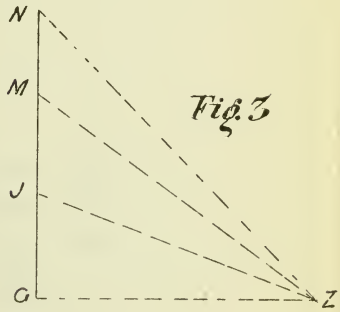


Fig. 3

FIGS. 5&6 X STANDS FOR B, C, E, & G

Fig. 1

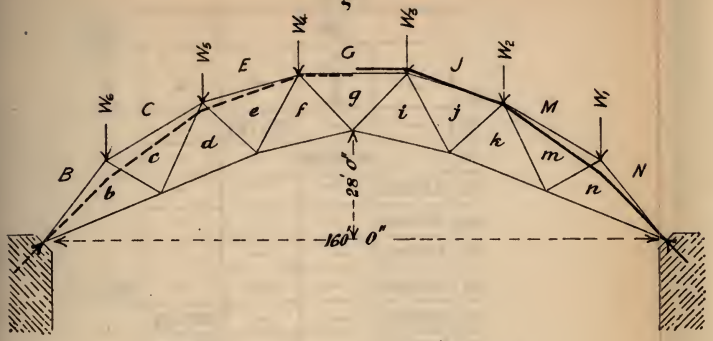


Fig. 4

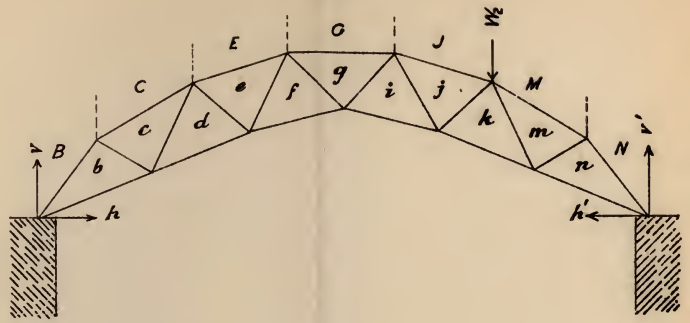
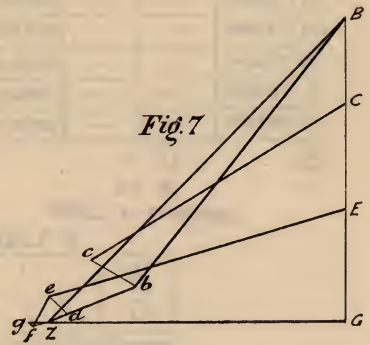


Fig. 7



Scales
Dimensions - 1 inch to 40 feet
Weights (figs. 2 & 3) - do. 20 tons.
do. (fig. 6) - do. 1 ton
do. (fig. 7) - do. 15 tons
do. (fig. 5) - ½ inch to 1 ton

Fig. 5

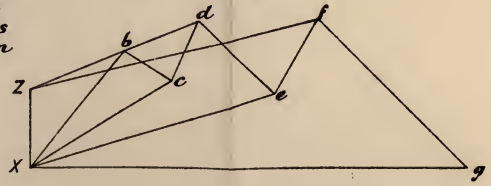


Fig. 2

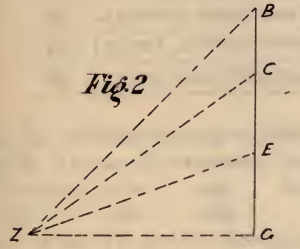


Fig. 3

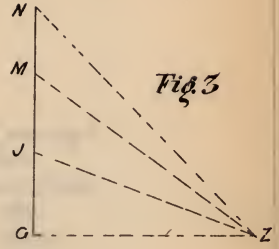
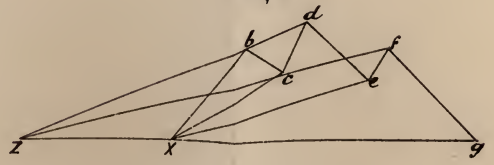


Fig. 6



NOTE - In figs. 5 & 6 X stands for B, C, E, & G

MEMBERS	W_5			W_6			
	V	V+V'+2	V'	V	V+V'+2	V'	
b	7·4704	—	—	7·4129	—	—	0·
b	7·4704	—	—	—	4·1183	—	0·
b	7·4704	—	—	—	—	0·8237	0·
c	7·4704	—	—	—	—	0·8237	0·
c	7·4704	—	—	—	—	0·8237	0·
d	—	5·0221	—	—	—	0·8237	3·
d	—	—	2·5738	—	—	0·8237	0·
e	—	—	2·5738	—	—	0·8237	0·
e	—	—	2·5738	—	—	0·8237	0·
f	—	—	2·5738	—	—	0·8237	21·
f	—	—	2·5738	—	—	0·8237	7·
g	—	—	2·5738	—	—	0·8237	0·

36

TABLE 3

	V	V'	TOTAL
W_1	0·8237	7·4129	8·2366
W_2	2·5738	7·4704	10·0442
W_3	4·3920	6·2553	10·6473
W_4	6·2553	4·3920	10·6473
W_5	7·4704	2·5738	10·0442
W_6	7·4129	0·8237	8·2366

odulus of elasticity = 11160 tons per sq
ngth of each member in inches
ct^al area do. do. in square inch
do. do. do. do.
ress due to unit horizontal force
do. da vertical do.
tal stress in tons
orizontal thrust in tons
action of left abutment
do. right do.

THE METALLIC ARCH.

TABLE 1

MEMBERS	a	l	l÷Ea=r	q	p	r.q.p	r.q²	W_1 v	W_2 v	W_2 v+v'÷2	W_2 v'	W_3 v	W_3 v+v'÷2	W_3 v'	W_4 v	W_4 v+v'÷2	W_4 v'	W_5 v	W_5 v+v'÷2	W_5 v'	W_6 v	W_6 v+v'÷2	W_6 v'	Σr.q.p.v	S	a'
bB	7·27	306	0·0038	0·76	1·90	0·0055	0·0022	0·8237	2·5738	—	—	4·3920	—	—	6·2553	—	—	7·4704	—	—	7·4129	—	—	0·1591	−32·90	7·37
bZ	2·31	387	0·0150	1·59	1·28	0·0305	0·0379	0·8237	2·5738	—	—	4·3920	—	—	6·2553	—	—	7·4704	—	—	—	4·1183	—	0·7818	−3·00	2·01
bc	1·12	193	0·0154	0·30	0·74	0·0034	0·0014	0·8237	2·5738	—	—	4·3920	—	—	6·2553	—	—	7·4704	—	—	—	—	0·8237	0·0759	+4·80	1·07
cC	6·43	350	0·0049	0·86	2·15	0·0091	0·0036	0·8237	2·5738	—	—	4·3920	—	—	6·2553	—	—	7·4704	—	—	—	—	0·8237	0·2033	−29·00	6·50
cd	1·29	306	0·0213	0·34	0·85	0·0061	0·0025	0·8237	2·5738	—	—	4·3920	—	—	6·2553	—	—	7·4704	—	—	—	—	0·8237	0·1363	−5·50	1·23
dZ	0·70	324	0·0415	2·02	2·37	0·1987	0·1693	0·8237	2·5738	—	—	4·3920	—	—	6·2553	—	—	—	5·0221	—	—	—	0·8237	3·9523	−1·95	0·43
de	0·49	230	0·0421	0·56	1·40	0·0330	0·0132	0·8237	2·5738	—	—	4·3920	—	—	6·2553	—	—	—	—	2·5738	—	—	0·8237	0·5756	+2·45	0·35
eE	6·68	311	0·0042	1·35	3·36	0·0190	0·0077	0·8237	2·5738	—	—	4·3920	—	—	6·2553	—	—	—	—	2·5738	—	—	0·8237	0·3314	−3·020	6·77
ef	0·69	273	0·0355	0·24	1·12	0·0096	0·0020	0·8237	2·5738	—	—	4·3920	—	—	6·2553	—	—	—	—	2·5738	—	—	0·8237	0·1651	−3·10	0·69
fZ	0·20	308	0·1380	2·48	3·88	1·3279	0·8488	0·8237	2·5738	—	—	4·3920	—	—	—	5·3236	—	—	—	2·5738	—	—	0·8237	2·1924	+1·55	0·34
fg	0·10	238	0·2133	0·82	2·71	0·4740	0·1454	0·8237	2·5738	—	—	4·3920	—	—	—	—	4·3920	—	—	2·5738	—	—	0·8237	1·3844	+0·35	0·08
gG=2	6·85	168	0·0022	2·00	5·71	0·0251	0·0088	0·8237	2·5738	—	—	4·3920	—	—	—	—	4·3920	—	—	2·5738	—	—	0·8237	0·3910	−30·75	6·89
								1·2408															3·60812			

TABLE 2

MEMBERS	SECT^al AREAS ABUTTING	SECT^al AREAS NON ABUT^ts
bB	7·31	12·27
bZ	2·01	8·31
bc	1·07	3·02
cC	6·50	12·03
cd	1·23	3·42
dZ	0·43	12·67
de	0·55	4·14
eE	6·77	15·48
ef	0·69	2·18
fZ	0·34	16·36
fg	0·08	5·47
gG	6·89	19·73

$$h = \frac{\Sigma r.q.p.v}{\Sigma r.q^2}$$

$$\therefore\ h = \frac{3·60812}{1·2408} = 29·08 \text{ tons}$$

Unit stress = 4·46 tons per square inch

\+ denotes tension
− do. compression

TABLE 3

	v	v'	TOTAL
W_1	0·8237	7·4129	8·2366
W_2	2·5738	7·4704	10·0442
W_3	4·3920	6·2553	10·6473
W_4	6·2553	4·3920	10·6473
W_5	7·4704	2·5738	10·0442
W_6	7·4129	0·8237	8·2366

E = modulus of elasticity = 11160 tons per squre inch
l = length of each member in inches
a = sect^al area do. do. in square inches (assumed)
a' = do. do. do. do. (deduced)
q = stress due to unit horizontal force
p = do. da vertical do.
S = total stress in tons
h = horizontal thrust in tons
r = reaction of left abutment
r = do. right do.

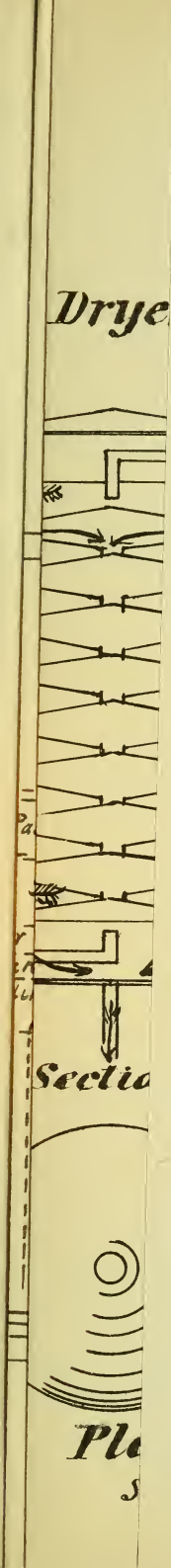
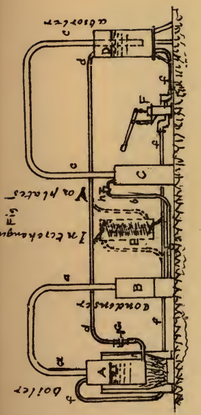
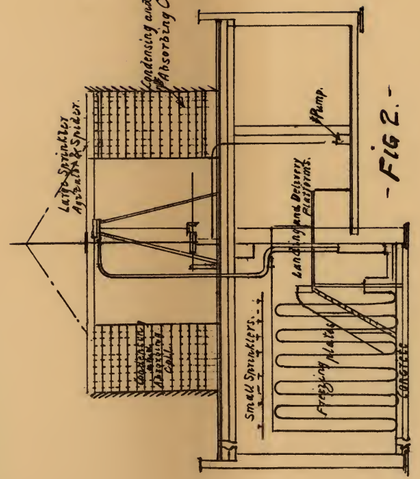

Drye
Sectio
Pl

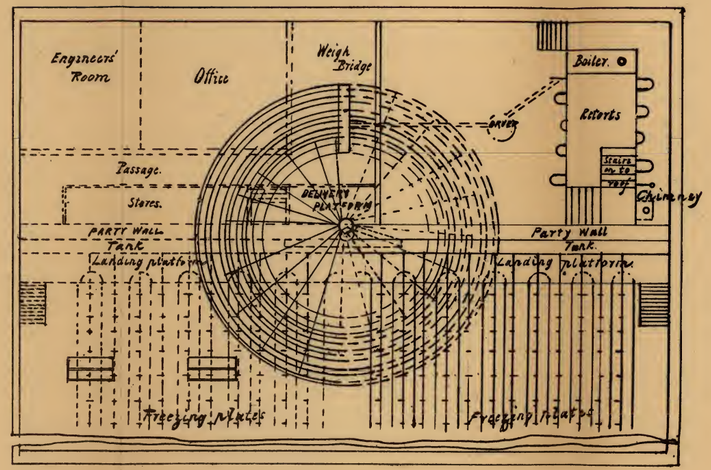
Fig 1





- Fig 2. -

- Fig. 3. -



Plan
Scale 1/16 to a foot.

Fig 4

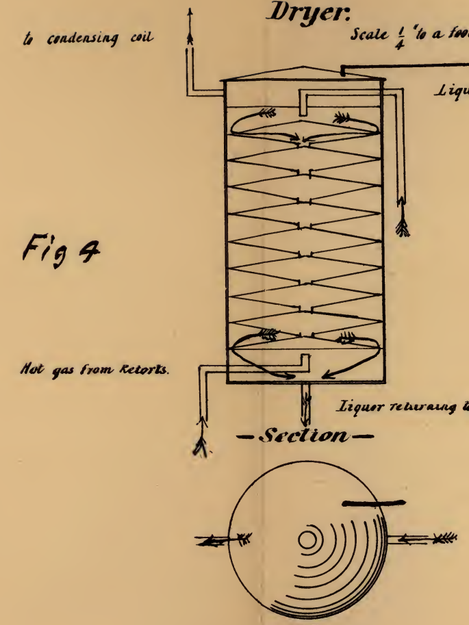
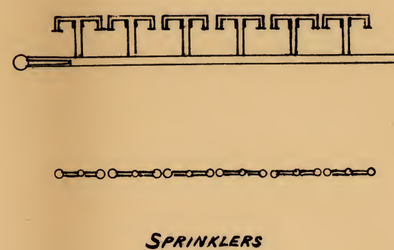


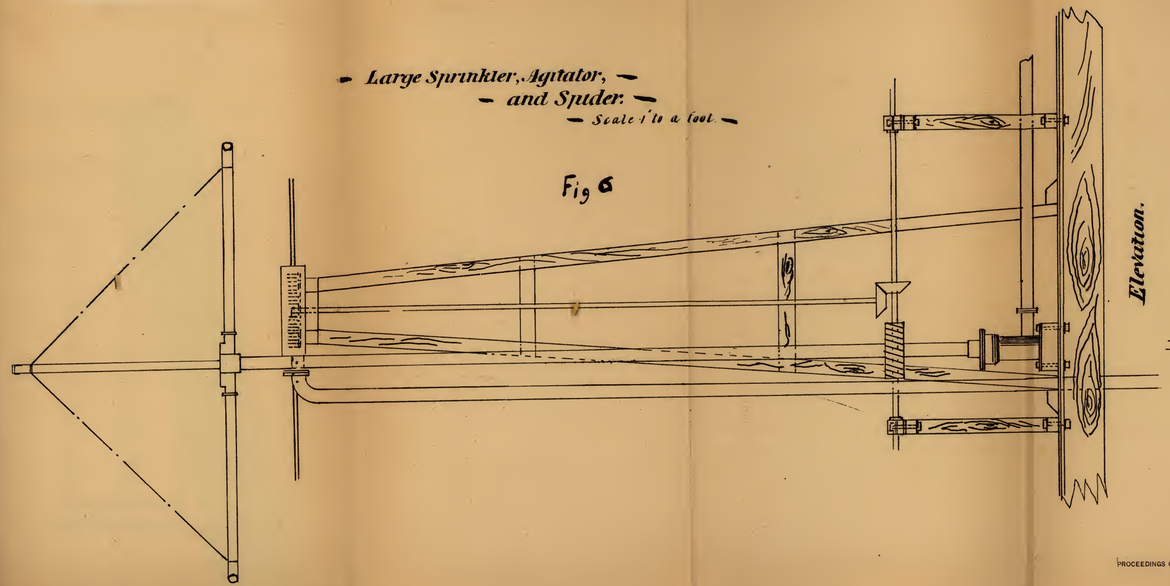
Fig 5



Large Sprinkler, Agitator, and Spider.

Scale 1 to a foot.

Fig 6



Elevation.

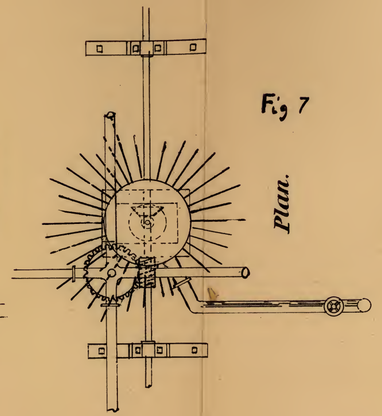
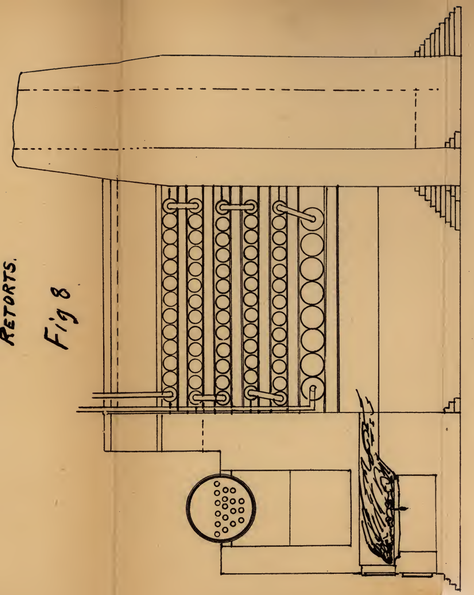


Fig 7

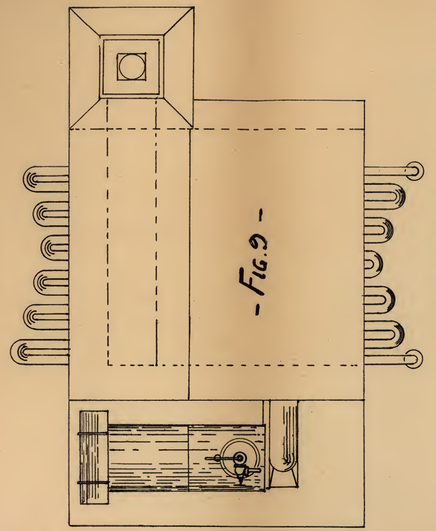
Plan.

RETORTS.

Fig 8

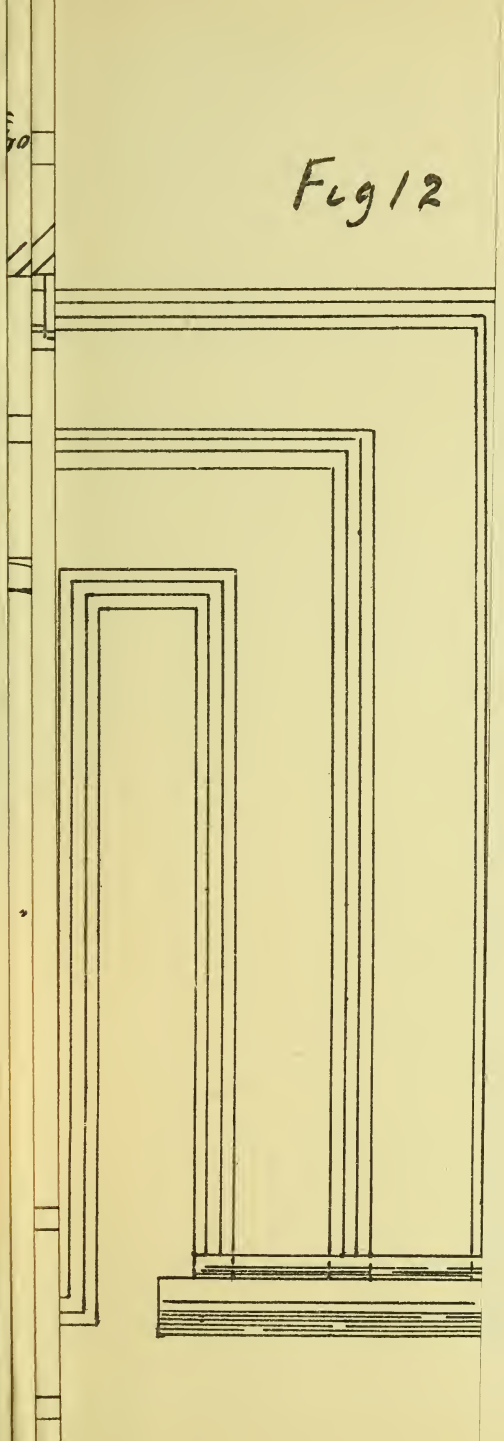


SECTION.



PLAN.

Fig 12



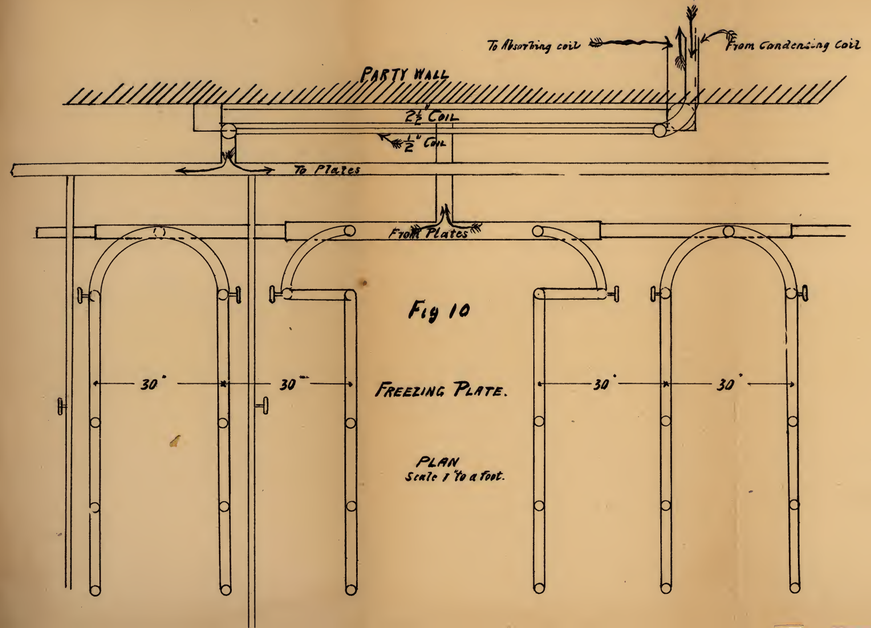


Fig 10

FREEZING PLATE.

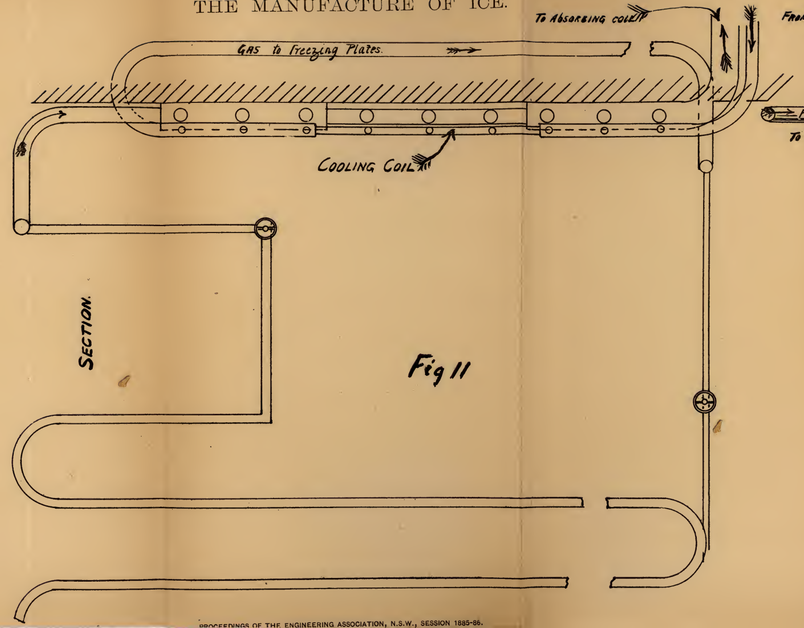


Fig 11

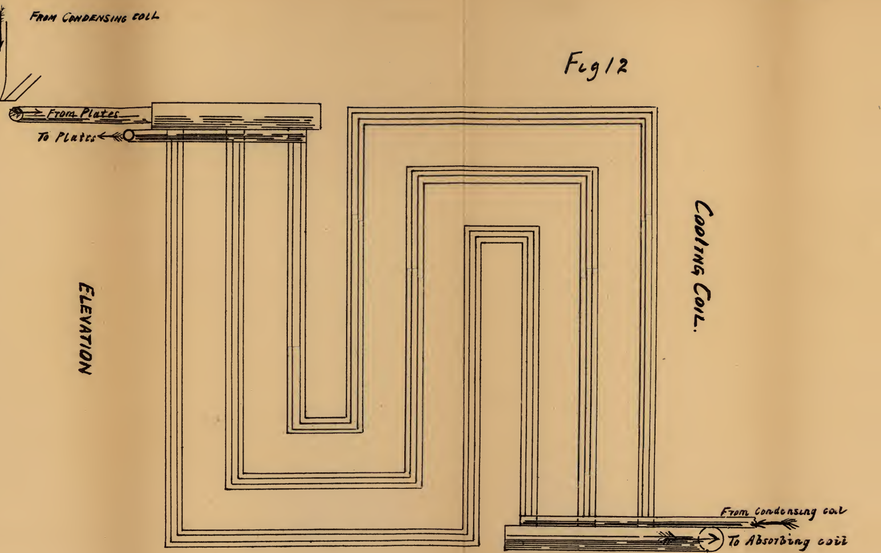


Fig 12

THIS BOOK BELONGS TO
THE AMERICAN SOCIETY
OF
MECHANICAL ENGINEERS,
AND IS NOT TO BE TAKEN
FROM THE LIBRARY.

CORBETT
BOOKBINDER
CASTLEREAGH ST.
SYDNEY

UNIVERSITY OF ILLINOIS-URBANA
3 0112 043282695